THE AQUATIC PLANT COMMUNITY IN ARROWHEAD LAKE, ADAMS COUNTY, WISCONSIN NOVEMBER 2010

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EXECUTIVE SUMMARY

Arrowhead Lake is located in the Town of Rome, Adams County, Wisconsin. The impoundment is 350 surface acres in size. Maximum depth is 30', with an average depth of 8'. The dam impounds Fourteen-Mile Creek downstream from the dams at Lower and Upper Camelot Lakes and Sherwood Lake, on its way to the Wisconsin River. There is a public boat ramp and a public swimming beach located on southwest side of the lake owned by The Adams County Parks Department.

Arrowhead Lake scores as "mesotrophic" in the three general parameters often used to gauge lake water health. With its phosphorus readings and chlorophyll a readings, moderate plant growth and occasional algal blooms would be expected.

Of the 44 species found in Arrowhead Lake in 2009, 40 were native and 4 were exotic invasives. In the native plant category, 28 were emergent, 2 were free-floating plants, and 11 were submergent species. Four exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass), *Potamogeton crispus* (Curly-Leaf Pondweed) and *Typha angustifolia* (Narrow-Leaved Cattail) were found.

Ceratophyllum demersum and *Potamogeton zosterformis* were the most frequently-occurring plants in Arrowhead Lake in 2009. *Ceratophyllum demersum* had the highest frequency of occurrence in the 2007 PI survey with an occurrence frequency of 25.71%. Other common plants were *Myriophyllum sibiricum, Myriophyllum spicatum* and *Potamogeton pusillus.*

Potamogeton zosteriformis was also the densest plant in Arrowhead Lake in 2009. The second densest plant was *Ceratophyllum demersum*. In the lake overall, none of the aquatic vegetation occurred at more than average growth density. In 2007, the densest plant was *Ceratophyllum demersum*. The next most densely-growing plant was the invasive *Myriophyllum spicatum*.

Based on dominance value, *Potamogeton zosteriformis* was the dominant aquatic plant species in Arrowhead Lake in 2009, but *Ceratophyllum demersum* was very close behind. In 2006, *Char*a spp was the dominant aquatic species found, with *Potamogeton pusillus* sub-dominant.

The Simpson's Diversity Index in 2009 for Arrowhead Lake was .91, showing good species diversity. This is the same as the 2006 SI, which was up slightly from the 2000 index of .89. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). The 2009 AMCI for Arrowhead Lake is 56, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes. The AMCI in 2006 was 55, and the 2000 reading was 56. Based on transect survey results, in Arrowhead Lake, often the greatest variety of plants has been found in waters less than 5 feet deep.

A point intercept aquatic plant survey was performed in 2010 and compared to the results of the one done previously in 2007. In the 2010 survey, the most frequently occurring aquatic plants were *Ceratophyllum demersum* and *Zosterella dubia*. In 2007, *Ceratophyllum demersum* and *Potamogeton pusillus* were tied for the most-frequently occurring aquatic plant. The species with the densest growth was *Ceratophyllum demersum* from the 2010 PI survey. In the 2007 survey, *Chara* spp., the macrophytic algae, was the most densely growing species. The most dominant plant in the 2010 PI survey was *Zosterella dubia*, with *Ceratophyllum demersum* sub-dominant.

The PI Simpson's Index in 2007 was .88, while the 2010 PI survey resulted in a SI of .91. The 2007 PI AMCI was 49, while the 2010 PI AMCI was 56. This is probably due the difference in method of plant collection, since the 2007 PI points for Arrowhead Lake included only 27 out of 525 points in water depths less than 5 feet, but permission was given for the 2010 PI survey to add points in shallower water.

MANAGEMENT RECOMMENDATIONS

1) Because aquatic vegetation is used by fish for a number of purposes (cover, feeding, spawning, etc), continued harvesting to open fishing lanes should continue in these areas. Removal should occur by hand in the shallower areas to be sure that entire plants are removed and to minimize the amount of disturbance to the sediment.

2) Some natural shoreline restoration and erosion control in several areas is still needed, especially on some of the bare steep points. Starting in 2010, the Arrowhead Lake Association, working with the Adams County Land & Water Conservation Department, will begin to restore several severely eroded points that it owns. Some treefall at various points have already taken large portions of the banks. These shore restoration designs will be tailored to the needs of the particular shore and will probably include combinations of planting, grading, bioenginerring and armoring.

3) To protect water quality, a buffer area of native plants needs to be restored on those many lake association-owned sites that now have seawalls or have traditional lawns mowed to the water's edge. Although the Arrowhead Lake Association owns the first hundred feet shoreward around the lake, they have been working with the landowners who use the shore area in front of their respective lots to install shore protection and provide buffers.

4) There are several points on the lake that consist of high bluffs with a great deal of sloughing soil and some falling trees. Within the last two years, the Arrowhead Lake Association has started working with Adams County Land &

Water Conservation Department to restore and protect these points to prevent further erosion and soil deposit into the lake. It is recommended that this process continue until all these points have been protected and stabilized.

5) The Tri-Lakes Management District and the Arrowhead Lake Association should continue to cooperate with the WDNR to monitor and, if possible, control the zebra mussel infestation in the lake to protect the aquatic plant community.

6) Stormwater management of the many impervious surfaces around the lake is essential to maintain the current quality of the lake water and prevent further degradation.

7) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore. The new state ban on phosphorus-containing fertilizer should help, but non-Wisconsin residents need to be reminded that using phosphorus-containing fertilizers from other states is illegal.

8) The aquatic plant management plan should continue to be reviewed annually. The mechanical harvesting plan should be revised to exclude the targeted harvesting for Eurasian Watermilfoil (EWM) that has been done in the last few years. Due to the significant increase in EWM, despite targeted harvesting, alternate methods of addressing EWM growth need to be developed.

9) The aquatic plant management plan also needs to address managing the Curly-Leaf Pondweed growth. This invasive appeared since the 2005-2006 aquatic plant surveys. If the plan is modified to include a series of actions to address this growth, perhaps its spread and establishment can be reduced.

10) The Tri-Lakes Management District may want to continue to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

11) No broad-scale chemical treatments of native aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

12) Fallen trees should be left at the shoreline or in the water to increase shore area habitat.

13) The Tri-Lakes Management District should continue involvement in water quality and invasive species monitoring through the Citizen Lake Monitoring Program, the Clean Boats, Clean Waters program and grants for AIS management.

14) Arrowhead Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs. Nutrients appear to have increased within the lake, so residents must take steps to reduce their nutrient inputs.

15) No drawdowns of water level except for DNR-approved purposes should occur.

16) The few sites where there is undisturbed shore, mostly in designated conservancy areas, should be maintained and left undisturbed.

17) The Tri-Lakes Management District should continue to review its lake management plan at least annually and continue to engage in water quality testing that ensures that its lake management plan takes into account all inputs from both the Arrowhead Lake surface ground watershed and inputs from Camelot & Sherwood Lakes, and addresses the concerns of this larger lake community.

18) Cooperation with the Adams County Parks Department in keeping the boat ramp and swimming beach in safe condition should help reduce any negative impacts caused by the heavy use of these public areas. A boat washing station at the park ramp area may help in decreasing other invasives from invading the lake.

19) The Tri-Lakes Management District, which includes Arrowhead Lake, has become a sanitary district and now requires tri-annual inspection of all septics, no matter what their date of installation. This program needs to continue, especially since at 1999 report of the lake area septic systems by MSA Professional Services found that septic absorption fields around the Tri-Lakes develop phosphorus loads in a shorter-than-anticipated time that may end up in the lake through groundwater flow, so that regular inspections may help reduced this buildup and discharge. Until Adams County gets its county program for regular inspection up and running for older septic system, the Tri-Lakes Management District should continue with the program it has already set up to make sure there aren't problems in the meantime.

THE AQUATIC PLANT COMMUNITY FOR ARROWHEAD LAKE
ADAMS COUNTY 2006-2010

I. INTRODUCTION

An updated transect aquatic macrophyte (plants) transect (line intercept) field study of Arrowhead Lake was conducted during August 2009 by a staff member and employees of the Tri-Lakes Management District. Previous quantitative vegetation studies Arrowhead Lake were done during July 2000 by the Wisconsin Department of Natural Resources; during July 2006 by staff from the Adams County Land & Water Conservation Department and the Tri-Lakes Management District; and in August 2007 by the Wisconsin Department of Natural Resources.

An updated point intercept aquatic plant survey was completed in 2010 by a staff member and employees of the Tri-Lakes Management District and compared to one completed in 2007 by staff of the Wisconsin Department of Natural Resources.

Information about the diversity, density and distribution of aquatic plants is an essential component in understanding the lake ecosystem due to the integral ecological role of aquatic vegetation in the lake and the ability of vegetation to impact water quality (Dennison et al, 1993). These studies will provide further information to be used for effective management of Arrowhead Lake, including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulation. The data will be compared to the prior study results and also used for future studies, offering insight into any changes within the lake.

Ecological Role: Lake plant life is the beginning of the lake's food chain, the foundation for all other lake life. Aquatic plants and algae provide food and oxygen for fish and wildlife, as well as cover and food for the invertebrates that many aquatic organisms depend on. Plants provide habitat and protective cover for aquatic animals. They also improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

Characterization of Water Quality: Aquatic plants can serve as indicators of water quality because of their sensitivity to water quality parameters such as clarity and nutrient levels (Dennison et al, 1993).

Testing has shown that Arrowhead Lake has hard water. The average hardness reading for the last 20 years in Arrowhead Lake is 162 milligrams/liter of Calcium Carbonate. Lake water pH has ranged from 6.4 to 8.16. Hard water lakes tend to produce more fish and aquatic plants than soft water lakes.

Background and History: Arrowhead Lake is located in the Town of Rome, Adams County, Wisconsin. The impoundment is 350 surface acres in size. Maximum depth is 30', with an average depth of 8'. The dam impounds Fourteen-Mile Creek downstream from the dams at Lower and Upper Camelot Lakes and Sherwood Lake, on its way to the Wisconsin River. There is a public boat ramp and a public swimming beach located on southwest side of the lake owned by The Adams County Parks Department.

Arrowhead Lake is accessible off of State Highway 13 by turning west onto either Apache Avenue, then north on 15th Avenue, or turning west on County D, then south onto 15th Ave. Heavy residential development around the lake is found along most of the lakeshore. The surface watershed is 39.9% residential; 30.1% woodlands; 11.7% outdoor recreation (mostly golf courses); 9.8% water; 4.9% industrial/commercial/governmental; and 3.7% open grassland. The ground watershed, which extends into Waushara County, has much irrigated and nonirrigated agriculture, except near to the lakes. There are endangered or threatened resources in the watershed which include the Karner Blue Butterfly, the Persius Dusky Wing Butterfly; the Red-Shouldered Hawk; and the natural communities of northern sedge meadow and shrub-carr. There are no reported archeological or historical sites in the Arrowhead Lake surface watershed.

A fishery inventory in October 2004 revealed that walleye and largemouth bass are abundant in Arrowhead Lake; bluegills and white suckers are common; yellow perch and northern pike are scarce.

Soils in the Arrowhead Lake surface watershed are sands of various slopes. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have low water-holding and low organic matter content, thus making them difficult to for vegetation establishment. These soils tend to be easily eroded by both water and wind.

Efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting. In the most recent years, these efforts have concentrated on mechanical harvesting and some hand-pulling. No chemicals have been used since 2000. Figures 1 and 2 summarize the chemical and mechanical aquatic plant management.

FIGURE 1: CHEMICAL TREATMENT SUMMARY

		Aquatic Herbicicides Applied to Arrowhead Lake				
Year	**Copper (lbs)**	**Cutrine (gal)**	**Aquathol (gal)**	**Hydrothol (gal)**	**Diquat (gal)**	**Rodeo (gal)**
1981	1400					
1982	125					
1983	150		7		6	
1984	75		14	52		
1985	300		41.5		15	
1986	610		30		10	
1987	350		5		5	
1988	375		22		10	
1989	1050					
1990	200				3	0.75
1991	475		5		3	
1992	300		10		10	
1993			10		20	
1994	785		6.25		3.75	
1995	725		24		9	
1996		55	11			11
1997		65				
1999			5		5	
2000			15		15	
Total	6920 lbs	121 gal	205.75 gal	52 gal	113.75 gal	11.75 gal

Both copper in pounds and cutrine in gallons added copper to Arrowhead Lake. Copper is an element and does not degrade any further. Copper is known to harm native mollusks (clams, mussels, snails) and invertebrates that serve as food for the fish. A significant number of pounds of copper now reside in the sediments of Arrowhead Lake.

Mechanical harvesting of aquatic plants in Arrowhead Lake started in 1995 and has continued through 2009. Plant samples are taken annually to a laboratory to be tested for the amount of phosphorus in milligrams per kilogram of aquatic plants. Figure 2 shows the approximate weight of aquatic vegetation removed from Arrowhead Lake from 1995 through 2010.

FIGURE 2: MECHANICAL HARVESTING SUMMARY

year	# of tons	# of pounds
1995	18.5	37,000
1996	49	98,000
1997	42.5	85,000
1998	107	214,000
1999	110.5	221,000
2000	137	274,000
2001	164	328,000
2002	57.3	114,600
2003	156.5	313,000
2004	148	296,000
2005	67.5	135,000
2006	209.4	418,800
2007	693	1,386,000
2008	296.9	593,800
2009	248.6	497,200
2010	399.1	798,200
total	2904.8	5,809,600

An aquatic plant survey was conducted by WDNR staff in 2000. This survey found that that the plant-like algae, *Chara* spp (muskgrass), was the most frequently-occurring aquatic "plant" species in Arrowhead Lake, closely followed by *Potamogeton pusillus* (small pondweed). No species occurred at more than 50% frequency. *Chara spp* also had the highest density, again followed by *Potamogeton pusillus.* On the lake overall, only these two occurred at more than average density. Although three invasives, *Myriophyllum spicatum* (Eurasian watermilfoil), *Phalaris arundinacea* (Reed Canarygrass), and *Potamogeton crispus* (Curly-Leaf Pondweed) were found in 2000, none of them occurred at high frequency, density or dominance.

A follow-up aquatic plant survey was conducted by Adams County Land & Water Conservation Department in 2006. *Stuckenia pectinata (*Sago pondweed) was the most frequently-occurring plant in Arrowhead Lake in 2006. Next closest in frequency of occurrence were *Chara* spp., *Potamogeton zosteriformis* (flat-stemmed pondweed), and *Najas flexilis* (bushy pondweed). *Stuckenia pectinata* was the densest plant in Arrowhead. None of the aquatic vegetation occurred at more than average density in the lake overall. The same three invasive plants were found again, none at high frequency, density or dominance.

In 2007, an aquatic plant survey was conducted on Arrowhead Lake as part of the Environmental Protection Agency's national lake survey. This survey used the Point Intercept method. The two most frequently-occurring aquatic plants in that survey were *Ceratophyllum demersum* (coontail) and *Potamogeton pusillus* (small pondweed). *Ceratophyllum demersum* was the densest plant found in 2007, but no species had a more than average density of growth. It was also the dominant plant, with *Potamogeton pusillus* subdominant. The invasive *Myriophyllum spicatum* was common, with the invasive *Potamogeon crispus* less common.

Since the 2000 plant survey, zebra mussels were found in Arrowhead Lake. The process of evaluating the level of infestation is still ongoing. Adams County has had divers examine the underwater dam structures, looking for zebra mussel accumulations. Plates were hung in various portions of the lake since 2004 and veliger sampling is conducted annually by the Wisconsin Department of Natural Resources. Many of the submerged plants in Arrowhead Lake collected in 2009 were heavily covered with zebra mussels. Zebra mussel shells wash up along the shore in Arrowhead Lake in most part of the lake.

II. METHODS

Field Methods

The 2000, 2006 and 2009 surveys were all performed with methods based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random transects. The shoreline was divided into 32 equal sections, with one transect placed randomly within each segment, perpendicular to the shoreline. The same transects were used for all three studies.

One sampling site was randomly chosen in each depth zone (0-1.5 feet; 1.5- feet; 5-10 feet; 10-20 feet) along each transect. Using long-handled, steel thatching rakes, four rake samples were taken at each site. Samples were taken from each quarter around the boat. Aquatic species present on each rake were recorded and given a density rating of 0-5.

A rating of 1 indicates the species was present on 1 rake sample.
A rating of 2 indicates the species was present on 2 rake samples.
A rating of 3 indicates the species was present on 3 rake samples.
A rating of 4 indicates the species was present on 4 rake samples.
A rating of 5 indicates that the species was abundantly present on all rake samples.

A visual inspection and periodic samples were taken between transects to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording species found.

Shoreline type was also recorded at each transect. Visual inspection was made of 50' to the right and left of the boat along the shoreline, 35' back from the shore (so total view was 100 feet x 3 feet'). Percent of land use within this rectangle was visually estimated and recorded.

The second method used was the Point Intercept Method in 2007 and 2010. This method involves calculating the surface area of a lake and dividing it (using a formula developed by the WDNR) into a grid of several points, always placed at the same interval from the next one(s). These points are related to a particular latitude and longitude reading. At each geographic point, the depth is noted and one rake is taken, with a score given between 1 and 3 to each species on the rake.

A rating of 1 = a small amount present on the rake;
A rating of 2 = moderate amount present on the rake;
A rating of 3 = large amount present on the rake.

A visual inspection was done between points to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Data Analysis:

The percent frequency (number of sampling sites at which it occurred/total number of sampling sites) of each species was calculated. Relative frequency (number of species occurrences/total of all species occurrences) was also calculated. The mean density (sum of species' density rating/number of sampling sites) was calculated for each species. Relative density (sum of species' density/total plant density) was also calculated. "Mean density where present "(sum of species' density rating/number of sampling sites at which the species occurred) was calculated. Relative frequency and relative density results were summed to obtain a dominance value. Species diversity was measured by Simpson's Diversity Index.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of Conservatism is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for the species found in the lake. The coefficient of conservatism is used to calculate the Floristic Quality Index, a measure of a plant community's closeness to an undisturbed condition.

To measure the quality of the plant community, an Aquatic Macrophyte Index was determined using the method developed by Nichols et al (2000). This measurement looks at the following seven parameters and assigns each of them a number on a scale of 1-10: maximum depth of plant growth; percentage of littoral zone vegetated; Simpson's diversity index; relative frequency of submersed species; relative frequency of sensitive species; taxa number; and relative frequency of exotic species. The average total for the North Central Hardwoods lakes and impoundments is between 48 and 57.

III. RESULTS

Physical Data

The aquatic plant community can be impacted by several physical parameters. Water quality, including nutrients, algae and clarity, influence the plant community; the plant community in turn can modify these boundaries. Lake morphology, sediment composition and shoreline use also affect the plant community. In addition, annual weather variations can also affect the aquatic plant community.

The trophic state of a lake is a classification of water quality (see Figure 3). Phosphorus concentration, chlorophyll a concentration and water clarity data are collected and combined to determine a trophic state. Eutrophic lakes are very productive, with high nutrient levels and large biomass presence. Oligotrophic lakes are those low in nutrients with limited plant growth and small fisheries. Mesotrophic lakes are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; those with a good and more varied fishery than either the eutrophic or oligotrophic lakes.

The limiting factor in most Wisconsin lakes, including Arrowhead Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. The 1986-2010 summer growing season average total phosphorus concentration in Arrowhead Lake was 24.5 micrograms/liter. Breaking this figure down, the total phosphorus average from 1986 through 1999 was 25.9 micrograms/liter. The average total phosphorus for 2000 through 2009 was 24.3 micrograms/liter. Thus, the average total phosphorus growing season figure has remained fairly consistent in Arrowhead Lake. This figure for average total phosphorus concentration is below the average for impoundments in Wisconsin. This concentration suggests that Arrowhead Lake is likely to have some nuisance algal blooms, but not as frequently as many impoundments, and probably localized, rather than whole lake blooms. This places Arrowhead Lake in the "good" water quality section for impoundments, and in the "mesotrophic" level for phosphorus.

Chlorophyll-a concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth. The 1991-2010 summer growing season average chlorophyll-a concentration in Arrowhead Lake was 14.3 micrograms/liter. This chlorophyll-a level places Arrowhead Lake at the "mesotrophic" level for chlorophyll-a.

Water clarity is a critical factor for plants. If aquatic plants receive less than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. The average summer Secchi disk clarity in Arrowhead Lake from 1986 through 2010 was 7.3 feet. This breaks down to an average from 1986 through 1999 was 6.2 feet, rising to an average of 7.6 feet for 2000 through 2010. This is fair water clarity, putting Arrowhead Lake into the "mesotrophic" category for water clarity.

It is normal for all of these values to fluctuate during a growing season. They can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. Phosphorus tends to rise in early summer, than decline as late summer and fall progress. Chlorophyll-a often rises in level as the water warms, then declines as autumn cools the water. Water clarity also tends to decrease as summer progresses, probably due to algae growth, improving as fall approaches.

Figure 3: Trophic States

Trophic State	Quality Index	Phosphorus	Chlorophyll-a	Sechhi Disk
		(ug/ml)	(ug/ml)	(ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	1 to 5	8 to 19
Mesotrophic	Good	**10 to 30**	5 to 10	**6 to 8**
	Fair	30 to 50	**10 to 15**	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Arrowhead Lake		**24.5**	**14.3**	**7.3**

According to these results, Arrowhead Lake scores as "mesotrophic" in the three general parameters often used to gauge lake water health. With such phosphorus readings and chlorophyll a readings, moderate plant growth and occasional algal blooms would be expected.

A 2000 groundwater study done by UW-Stevens Point indicated that drawdowns in Camelot and Sherwood Lakes resulted in increases of 3000% in ammonium and 700% in reactive phosphorus in part of Arrowhead Lake (B.Shaw et al, 2001). Such an increase in these factors may also stimulate aquatic plant growth and would most certainly increase algae growth. A 2002 Limnological Investigation by the U.S. Army Corps of Engineers revealed that chlorophyll a and total phosphorus increased in Arrowhead Lake, compared to Camelot and Sherwood Lakes, suggesting internal loading of phosphorus. However, Secchi transparency was greater in Arrowhead Lake.

Lake morphology is an important factor in distribution of lake plants. Duarte & Kalff (1986) determined that the slope of a littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support higher plant growth than steep slopes (Engel 1985).

Arrowhead Lake is a narrow lake that lies at the end of a series of lakes that are originally fed by a very large, multi-county multi-stream system. Much of the lake is shallow, although there are some areas of steeper drop-offs within the lake near the dam. With good water clarity and shallow depths, plant growth may be favored in much of Arrowhead Lake, since the sun reaches much of the sediment to stimulate plant growth.

Sediment composition can also affect plant growth, especially those rooted. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a particular location.

Figure 4: Sediment Distribution in Arrowhead Lake

Sediment	Type	Zone 1	Zone 2	Zone 3	Zone 4	Overall
Hard	Sand	59.38%	75.00%	71.88%	90.91%	70.34%
	Sand/Rock	21.88%	3.13%			6.78%
	Rock	6.24%				1.69%
Mixed	Sand/Peat		3.12%	6.25%	9.09	4.24%
	Sand/Peat/Rock		3.13%			.85%
Soft	Muck	12.50%	12.50%	15.63%		6.78%
	Peat		3.12%			.85%

Most of the sediment in Arrowhead Lake is hard, with little natural fertility and low available water holding capacity. Although such sediment may limit growth, most hard sediment sites in Arrowhead Lake were vegetated. 90.8% sample sites were vegetated in Arrowhead Lake, no matter what the sediment. Most sites without vegetation appeared to have been hand-harvested.

Shoreline land use often strongly impacts the aquatic plant community and thus the entire aquatic community. Impacts can be caused by increased erosion and sedimentation and higher run-off of nutrients, fertilizers and toxins applied to the land. Such impacts occur in both rural and residential settings.

In the 2009 shoreland review, herbaceous vegetation had the highest frequency of occurrence (nearly 97%), but covered less than 31% of the shore. Some type of native vegetation covered just over 65% of the shore, up from 48% in 2006. Since 2006, there has been an ongoing effort on Arrowhead Lake, aided by a lake management grant from the Wisconsin Department of Natural Resources, to improve the shoreline area. However, some type of disturbed shore still covers nearly 35% of the shore.

FIGURE 5: Shoreland Coverage on Arrowhead Lake

	2000	**2006**	**2009**
Shore Type			
Wooded	30.0%	28.6%	31.8%
Herbaceous	16.2%	18.1%	30.8%
Shrub	1.8%	2.8%	3.0%
Bare Sand	11.7%	5.8%	3.6%
Eroded	-	6.4%	1.7%
Gravel	-	0.5%	0.9%
Cultivated Lawn	29.0%	16.6%	15.4%
Hard Structure	2.0%	8.0%	4.7%
Rock Riprap	3.8%	11.5%	6.8%
Pavement/Other Rock	5.5%	1.7%	1.3%

Macrophyte Data

Figure 6: Plants Found in Arrowhead Lake 2000-2010

Scientific Name	Common Name	Type	_	_	_	_	_
			2000	2006	2007	2009	2010
Asclepis incarnata	Swamp Milkweed	Emergent	_	_	_	x	x
Aster lanceolatus	White Panicle Aster	Emergent	_	_	_	x	
Bidens cernuus	Nodding BeggarsTick	Emergent	_	_	_	x	
Bidens frondosus	Common Beggars Tick	Emergent	_	_	_	x	
Bidens trichosperma	Tall Swamp Marigold	Emergent	_	_	_	x	
Boehmeria cylindrica	Small Spike Flalse Nettle	Emergent	_	_	_		x
Calamagrostic canadensis	Bluejoint Grass	Emergent	_	_	_	x	
Carex spp	Sedges	Emergent	_	_	_	x	
Carex comosa	Bristly Sedge	Emergent	_	_	_	x	
Ceratophyllum demersum	Coontail	Submergent	x	x	x	x	
Chara spp	Muskgrass	Submergent	x	x	x	x	
Chelone glabra	Turtlehead	Emergent					x
Cicuta bulbifera	Bulb-Bearing Water Hemlock	Emergent				x	x
Cornus amomum	Silky Dogwood	Emergent				x	x
Cornus racemosa	Gray Dogwood	Emergent				x	x
Cyperus bipartitus	Shining Sedge	Emergent					x
Decodon vertticillatus	Swamp Loosestrife	Emergent		x			
Eleocharis acicularis	Needle Spikerush	Emergent		x			
Eleocharis palustris	Common Spikerush	Emergent					x
Elodea canadensis	Waterweed	Submergent	x	x	x	x	x
Elymus canadensis	Canada Wild Rye	Emergent				x	
Epilobium leptophyllum	American Marsh Willow Herb	Emergent					x
Equisetum hymenale	Pipes	Emergent				x	x
Eupatorium perfoliatium	Boneset	Emergent					x
Euthamia graminifolia	Grass-leaved Goldenrod	Emergent					x
Gentian andrewsii	Bottle Gentian	Emergent				x	
Hypericum perfolatum	Common St John's Wort	Emergent				x	
Ilex verticillatus	Common Winterberry	Emergent					x
Impatiens capensis	Jewelweed	Emergent				x	x
Iris versicolor	Blue-Flag Iris	Emergent		x			x
Lemna minor	Lesser Duckweed	Free-Floating	x	x	x	x	x
Lycopus americanus	American Bugleweed	Emergent					x
Lycopus uniflorus	Northern Bugleweed	Emergent				x	x
Myriophyllum heterophyllum	Various-Leaved Milfoil	Submergent				x	x
Myriophyllum sibiricum	Northern Milfoil	Submergent	x	x	x	x	x
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent	x	x	x	x	x
Najas flexilis	Bushy Pondweed	Submergent	x	x	x	x	x
Onoclea sensibilis	Sensitive Fern	Emergent		x		x	x

Panicum virgatum	Switchgrass	Emergent				x	
Phalaris arundinacea	Reed Canarygrass	Emergent	x	x		x	x
Potamogeton crispus	Curly-Leaf Pondweed	Submergent	x	x	x	x	x
Potamogeton foliosus	Leafy Pondweed	Submergent	x	x			
Potamogeton freisii	Narrow-Leaf Pondweed	Submergent			x		
Potamogeton illinoensis	Illinois Pondweed	Submergent		x			
Potamogeton nodusus	Long-Leaf Pondweed	Submergent		x			x
Potamogeton pusillus	Small Pondweed	Submergent	x	x	x	x	x
Potamogeton zosteriformis	Flat-Stem Pondweed	Submergent	x	x	x		x
Prunella vulgaris	Common Heal-all	Emergent				x	x
Ranunculus aquatilis	Water Crowfoot	Submergent			x		x
Ranunculus longirostris	Water Buttercup	Submergent	x	x			
Rumex spp	Water Dock	Emergent				x	x
Sagittaria latifolia	Arrowhead	Emergent		x	x	x	x
Salix spp	Willow	Emergent	x	x		x	x
Schoenoplectus tabernaemontani	Soft-Stem Bulrush	Emergent		x	x	x	x
Scirpus cyperinus	Woolgrass	Emergent					x
Silphium terebinthinaceum	Prairie Dock	Emergent				x	
Solidago nemoralis	Field Goldenrod	Emergent				x	
Solanum dulcamara	Bittersweet Nightshade	Emergent					x
Spirodela polyrhiza	Greater Duckweed	Free-Floating	x	x	x		x
Stuckenia pectinata	Sago Pondweed	Submergent	x	x	x	x	x
Typha angustifolia	Narrow-Leaf Cattail	Emergent	x	x		x	x
Vallisneria americana	Water Celery	Submergent	x	x	x	x	x
Verbena hastata	Blue Vervain	Emergent				x	x
Wolffia columbiana	Watermeal	Free-Floating	x	x	x	x	x
Zosterella dubia	Water Stargrass	Submergent	x	x	x	x	x

SPECIES PRESENT-2009

Of the 44 species found in Arrowhead Lake in 2009, 40 were native and 4 were exotic invasives. In the native plant category, 28 were emergent, 2 were free-floating plants, and 11 were submergent species. Four exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass), *Potamogeton crispus* (Curly-Leaf Pondweed) and *Typha angustifolia* (Narrow-Leaved Cattail) were found.

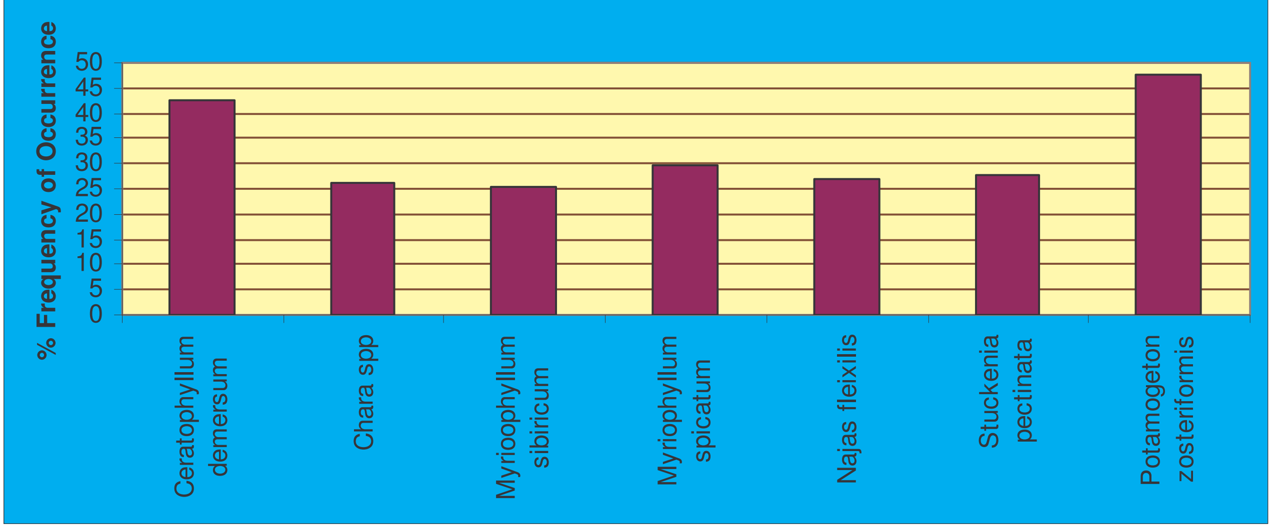
SPECIES PRESENT-2010

Of the 47 species found in Arrowhead Lake in 2010, 43 were native and 4 were exotic invasives. In the native plant category, 27 were emergent, 3 were free-floating plants, and 13 were submergents. The same four exotics were found in the PI survey in 2010 as in the transect survey in 2009.

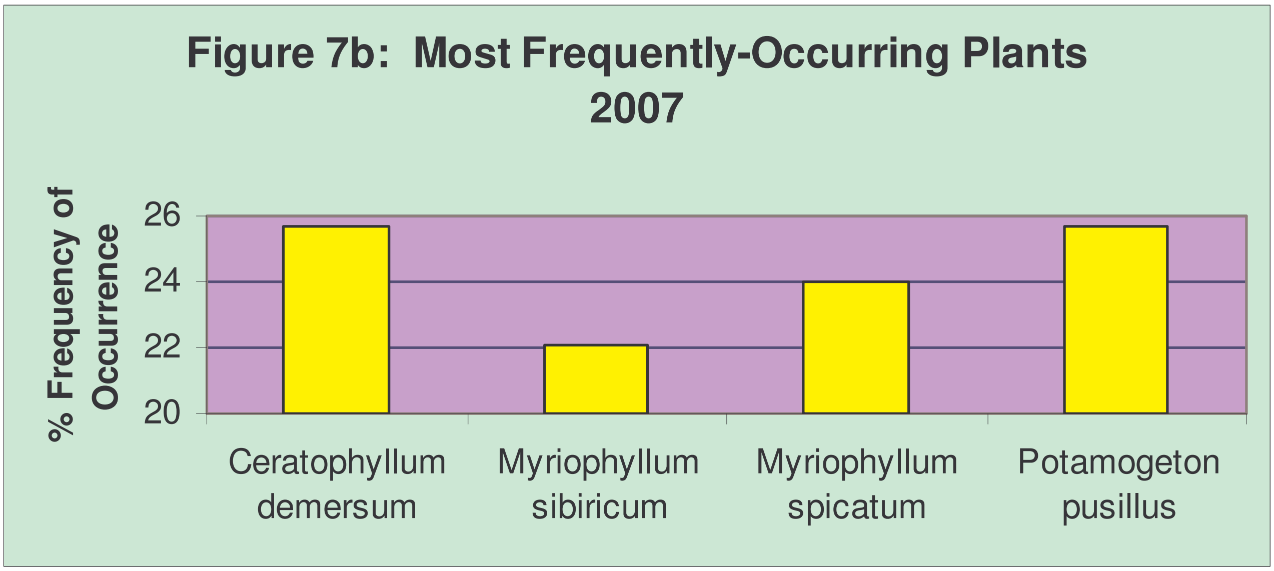
FREQUENCY OF OCCURRENCE

Ceratophyllum demersum and *Potamogeton zosteriformis* were the most frequently-occurring plants in Arrowhead Lake in 2009, with occurrence frequencies of 42.62% and 47.52 % frequency. No species had an occurrence frequency over 48%. In 2000, no species reached a frequency of 50% of greater in the lake overall, although *Chara* spp had an overall occurrence frequency of 44.95%. In 2006, only *Stuckenia pectinata* had a frequency of occurrence over 50%. Its frequency of occurrence was down in 2009 and 2010, which may at least partly be due to the cessation of annual winter drawdowns in the Camelot and Sherwood Lakes. This aquatic plant has been known to be encouraged by drawdowns (Jackson & Starrett, 1959).

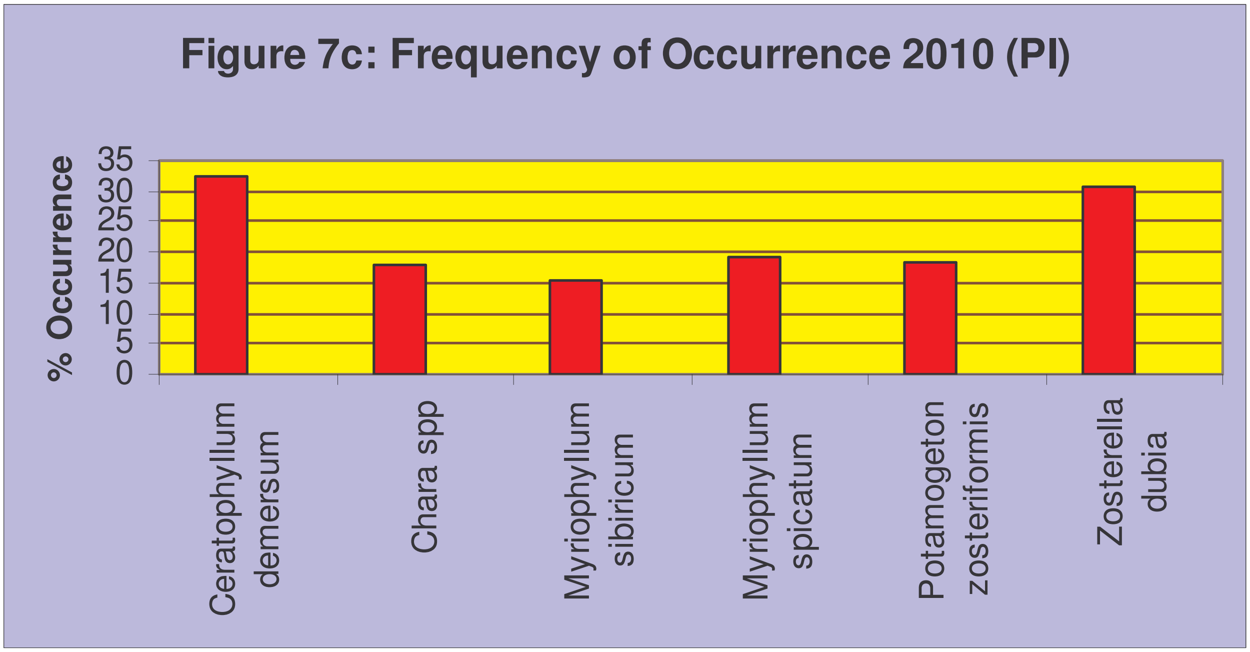
Figure 7a: Most Frequently Occuring Plants 2009



Ceratophyllum demersum had the highest frequency of occurrence in the 2007 PI survey with an occurrence frequency of 25.71%. Other common plants were *Myriophyllum sibiricum, Myriophyllum spicatum* and *Potamogeton pusillus. Chara* spp, the most frequently occurring "plant" in 2009 only had a frequency of occurrence just over 10% in 2007.

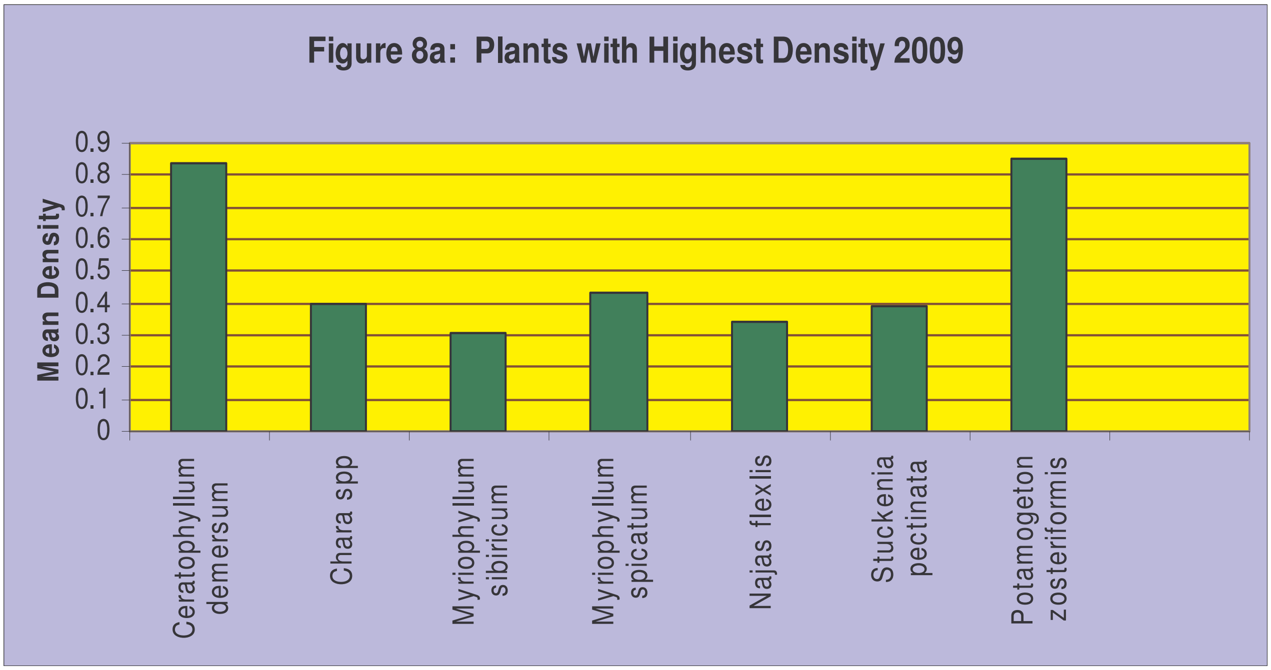


In the 2010 PI survey, *Ceratophyllum demersum* had the highest frequency of occurrence (33%), with *Zosterella dubia* close behind. No species had a frequency of occurrence over 33%. Other fairly frequent species included *Chara* spp., *Myriophyllum sibiricum, Myriophyllum spicatum* and *Potamogeton zosteriformis.*

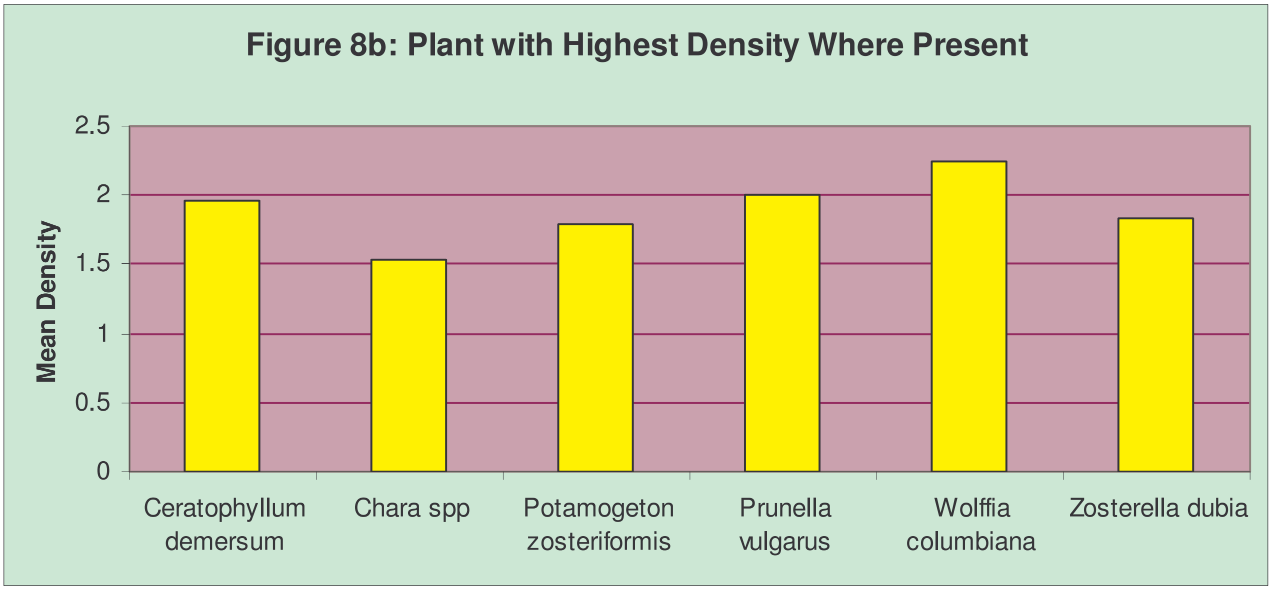


DENSITY OF OCCURRENCE

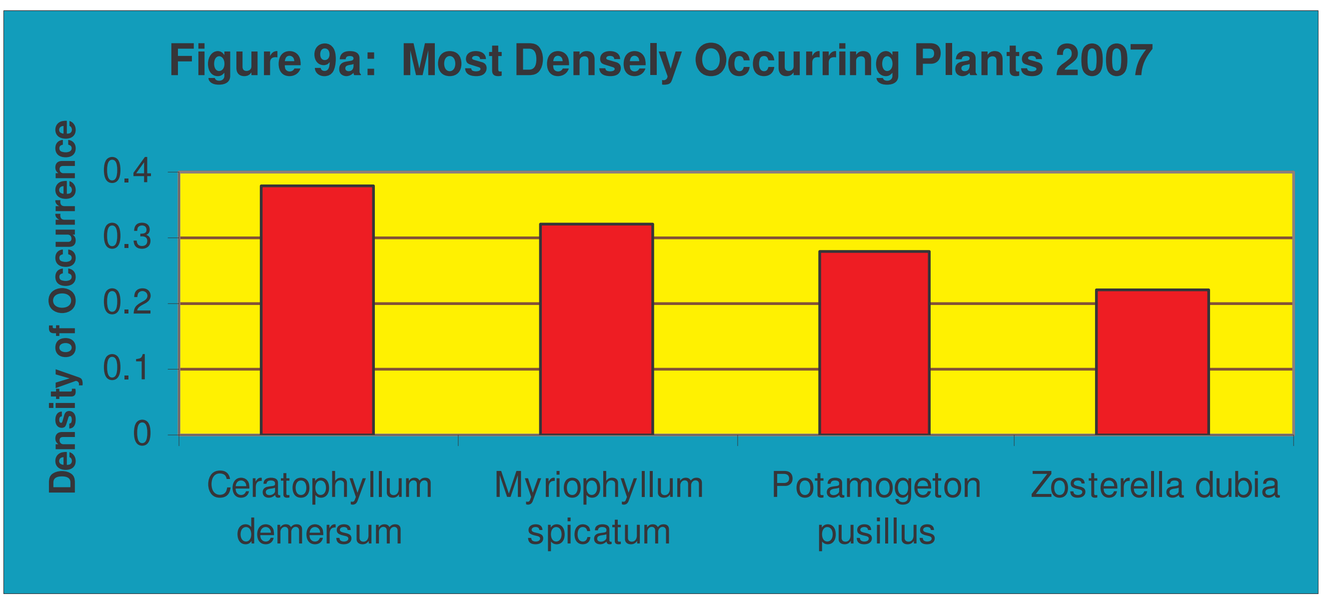
Potamogeto zosteriformis was also the densest plant in Arrowhead Lake in 2009. The second densest plant was *Ceratophyllum demersum*. In the lake overall, none of the aquatic vegetation occurred at more than average growth density. Most of the aquatic species grew at fairly low densities.



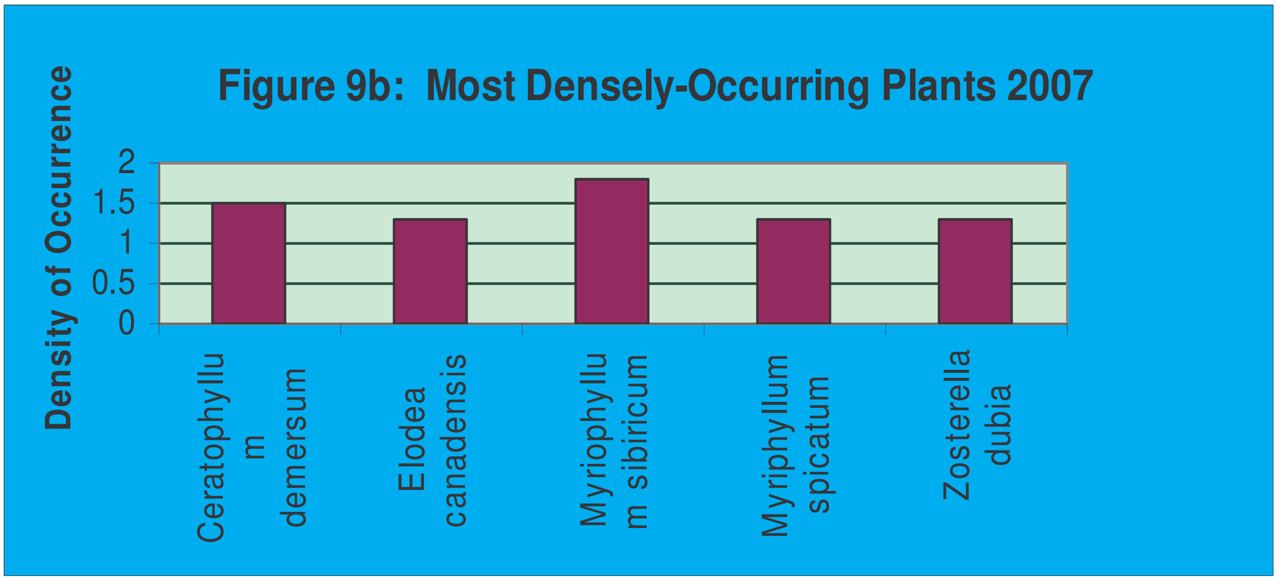
The picture is slightly different when density where present is examined. This figure looks not at how dense the plant growth is over all the lake, but how densely it occurs at the sites where it is found. One species, *Wolffia columbiana*, had a higher than average density of growth where present (more than 50%). Three other species were just below a growth density of 50%: *Ceratophyllum demersum*, *Zosterella dubia*, and *Potamogeton zosteriformis*. While *Wolffia columbiana* is a free-floating species that may not interfere with fish habitat and recreational use, the three species that were approaching a higher than average density where present are all submergent plants that do affect fish habitat and may affect recreational use.



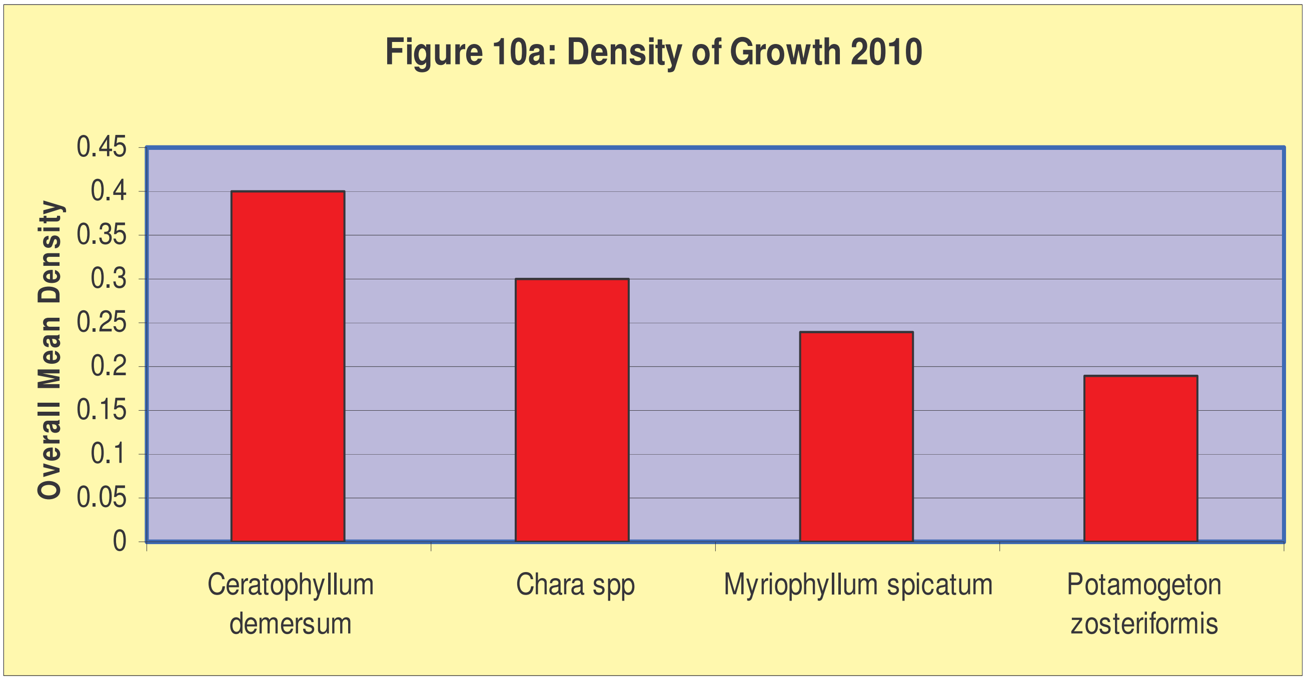
In 2007, the densest plant was *Ceratophyllum demersum,* with an overall density of growth. The next most densely-growing plant was the invasive *Myriophyllum spicatum*.

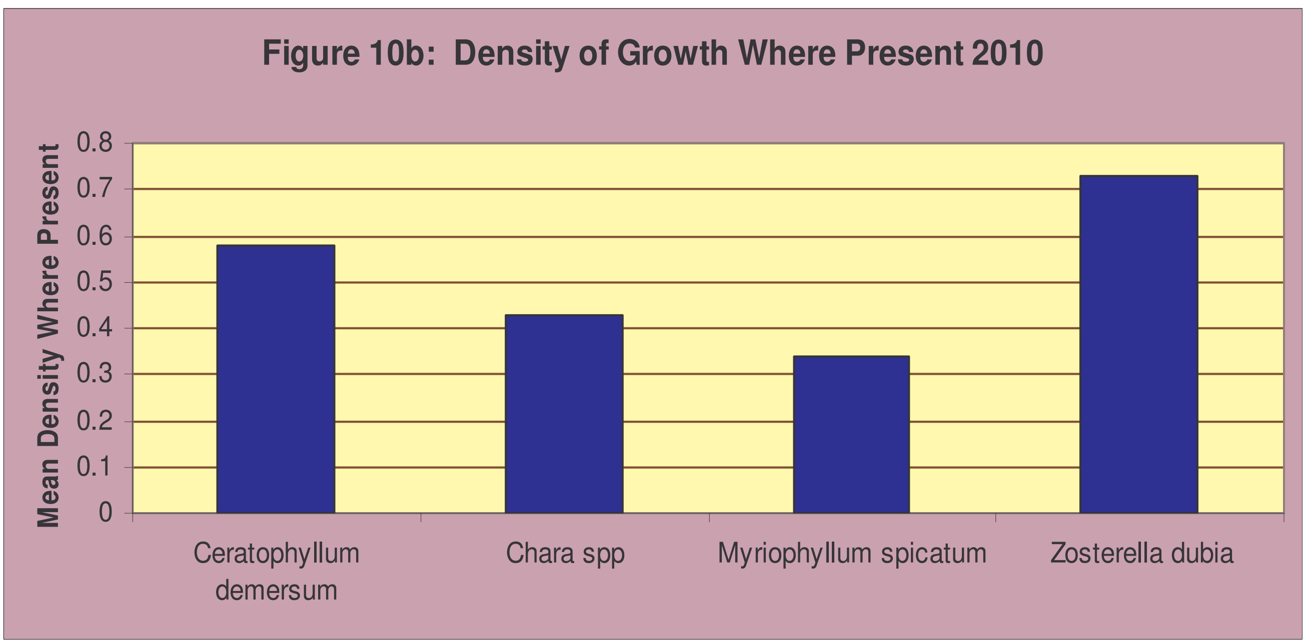


When considering density of growth where present, the picture again is some what different. *Myriophyllum sibiricum* takes over the top spot as the plant with the highest density of growth where present, with *Ceratophyllum demersum* dropping to second, followed by *Myriophyllum spictaum*, *Elodea canadensis* and *Zosterella dubia.*



In 2010, the PI survey also showed that *Ceratophyllum demersum* was the most densely-occurring aquatic species. The next most densely-occurring species was the macrophytic algae, *Chara* spp. As some of the other surveys results showed, looking at density of growth where present resulted in a different species as the most densely-growing plant. *Zosterella dubia* was the most densely growing plant where vegetation was present in 2010. No species had a higher than average growth density.

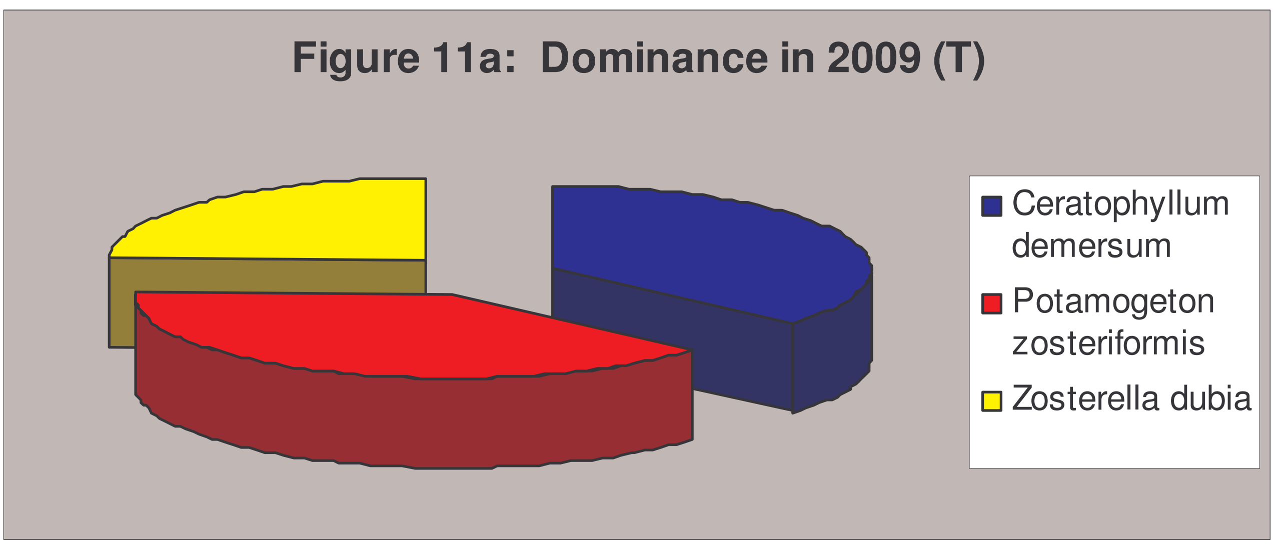




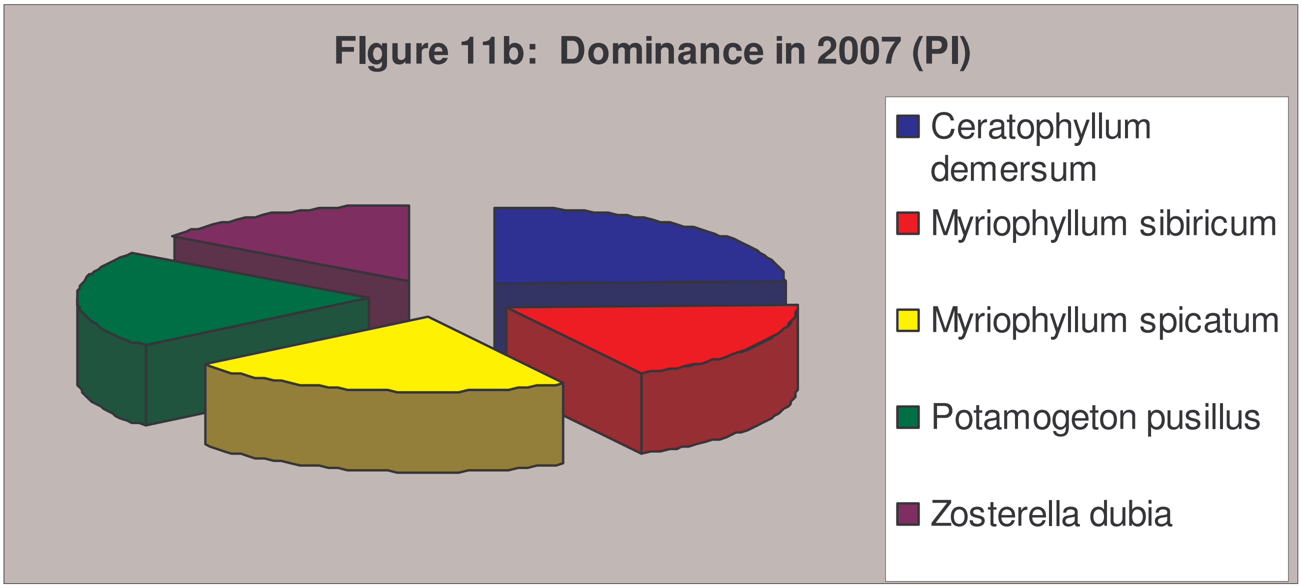
These figures show a decrease in density of growth since 2000 and 2006 (transect surveys). In 2000, 11 species had a greater than average growth density where present. In 2006, 13 species had a greater than average density of growth where present. In 2007, no species found had a greater than average density of growth where present. In 2009, the figure was 1 species. In 2010, no species had a greater than average growth density. It is too early to determine whether this decrease in growth density is going to continue.

DOMINANCE

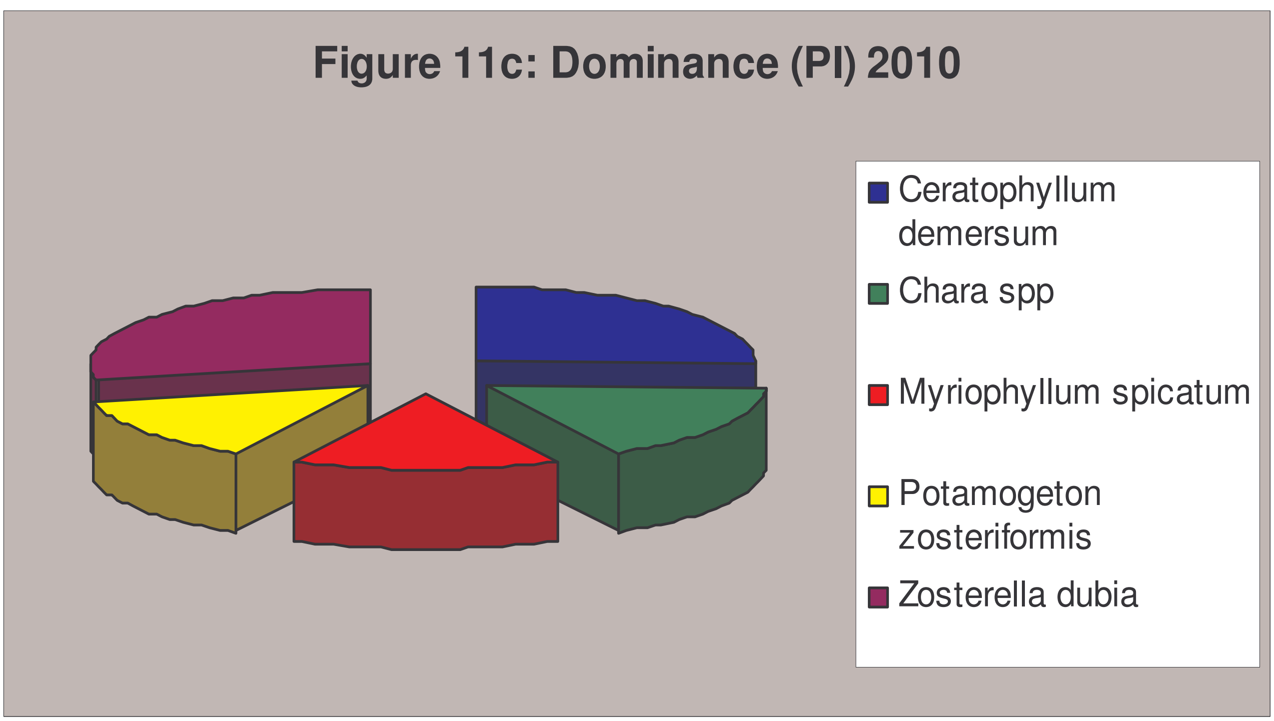
Relative frequency and relative density are combined into a dominance value that demonstrates how dominant a species is within its aquatic plant community. Based on dominance value, *Potamogeton zosteriformis* was the dominant aquatic plant species in Arrowhead Lake in 2009, but *Ceratophyllum demersum* was very close behind. Also occurring abundantly were *Chara* spp, *Myriophyllum sibiricum, Myriophyllum spicatum Najas flexilis, Potamogeton pectinatus* and *Zosterella dubia*.



In 2007, *Ceratophyllum demersum* was the dominant plant found, with *Myriophyllum spicatum* and *Potamogeton pusillus* sub-dominant. *Myriophyllum sibiricum* and *Zosterella dubia* were close behind.



In the 2010 PI survey, *Zosterella dubia* was the dominant aquatic species, with *Ceratophyllum demersum* falling to sub-dominant. Other common species included *Chara* spp., *Myriophyllum spicatum* and *Potamogeton zosteriformis.*

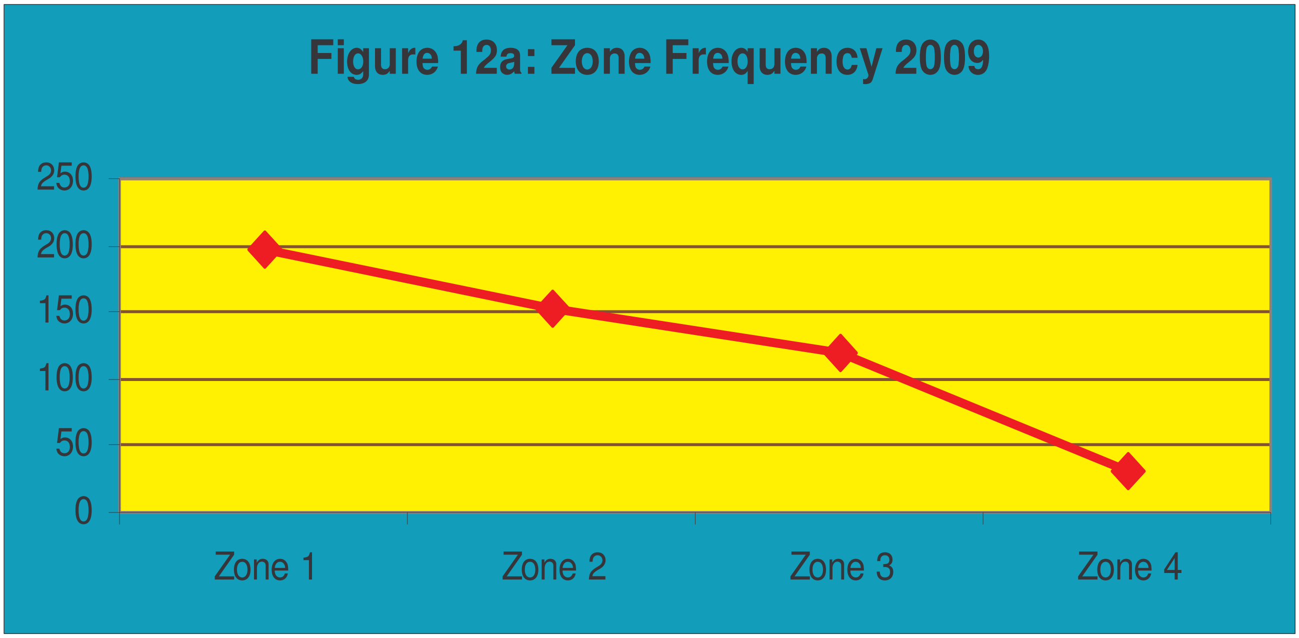


DISTRIBUTION

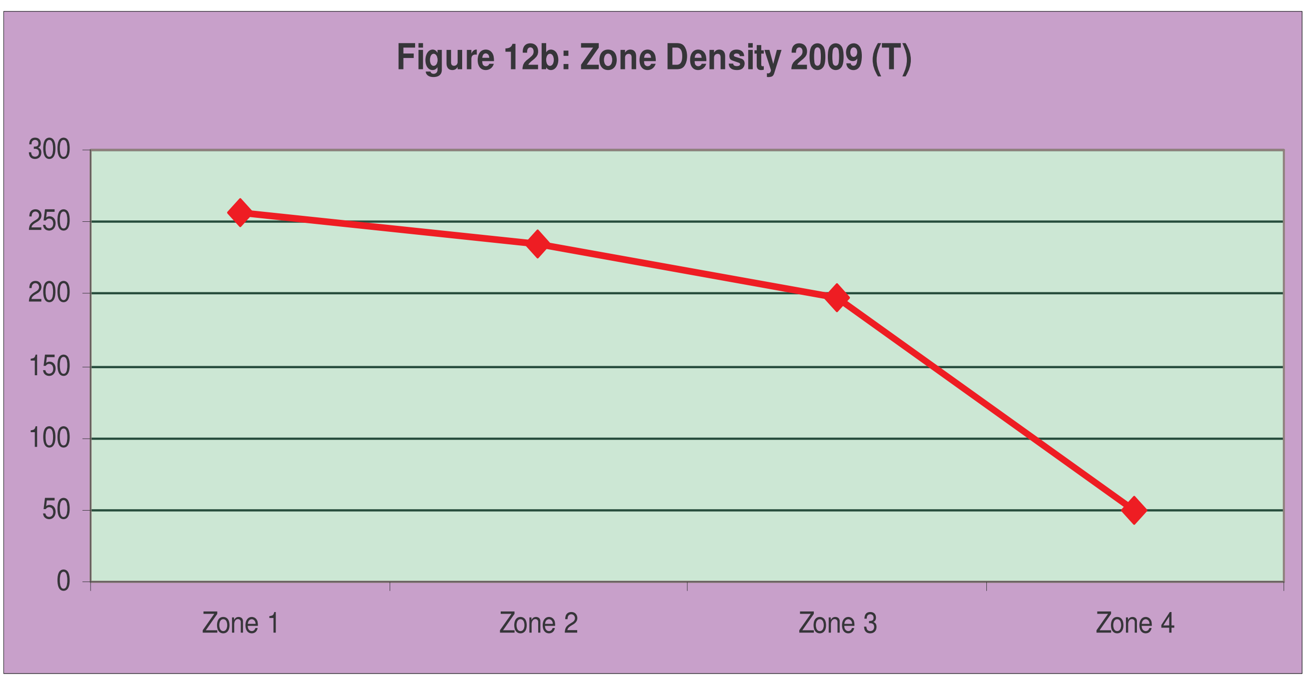
Aquatic plants occurred at 91% of the sample sites in Arrowhead Lake to a maximum rooting depth of 14 feet in 2009 (transect). In 2000, aquatic plants occurred at 80.7% of the sample sites, with a maximum rooting depth of 15 feet (transect). In 2006, aquatic plants were found at 91% of the sample sites to a depth of 16 feet (transect). In 2007, aquatic plants were found rooting up to a depth of 15.5 feet (PI). In 2010, *Potamogeon zosterformis* was found in 19.3 feet of water (PI). Free-floating plants were found in three depth zones in 2006; they were found only in the shallowest zone in 2000. They were found in Zones 1 and 2 in 2009.

Secchi disc readings are used to predict maximum rooting depth for plants in a lake (Dunst, 1982). Based on the average summer Secchi disc readings, the predicted maximum rooting depth in Arrowhead Lake would be 10.5 feet**.** During the 2009 aquatic plant survey, rooted plants were found at a depth of 14 feet, i.e., rooted plants were at a depth substantially more than that to be expected by Dunst calculations. The same is true of the 2010 survey, which showed a rooted aquatic plant at just over 19 feet of depth This may be due to the greater water clarity in the summers of 2009-2010 of 8.1 feet, perhaps due to fewer plants and less boat traffic, due to the cooler weather in summer 2009 and the large amount of rain in 2010

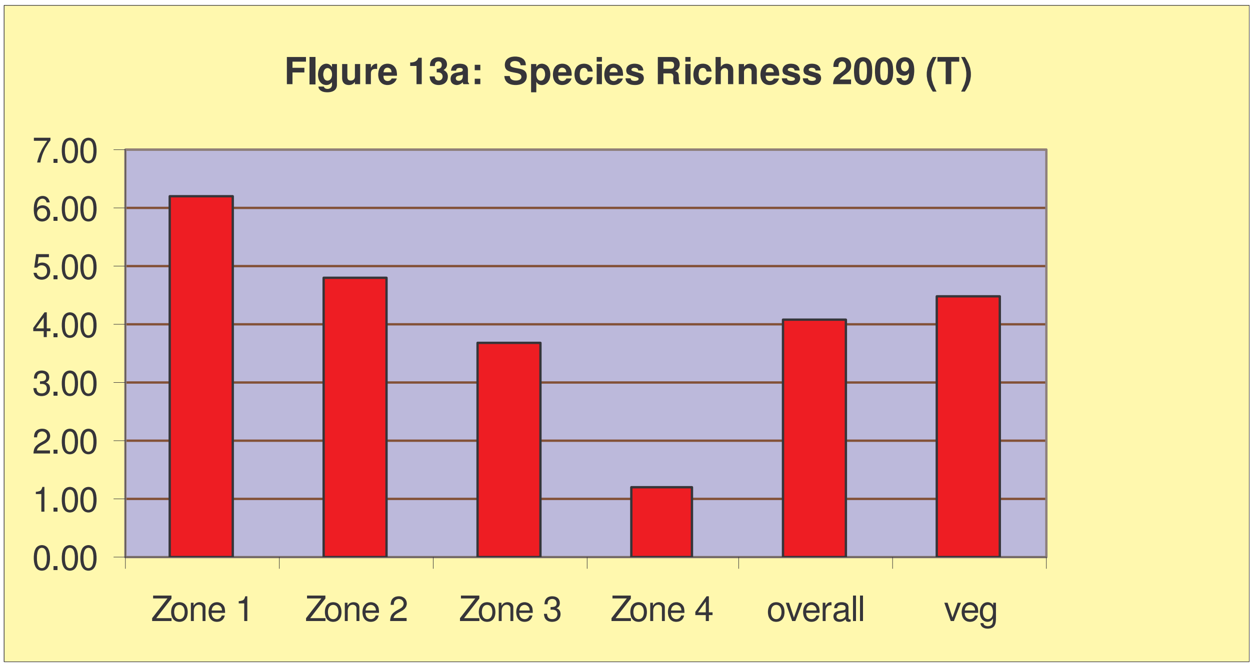
In the 2007 PI survey, aquatic plants were found at 61.1% of the sample sites. In the 2010 PI survey, they were found at 69.1% of the sites. These figures differ substantially from the 2009 transect survey, which found plants at 91% of the sample sites. This difference is explained by the differing methods—in a PI survey, sample sites occur in water depths unlikely to sustain plant growth, while the transect method sampling sites are confined to 20 feet of depth or less..



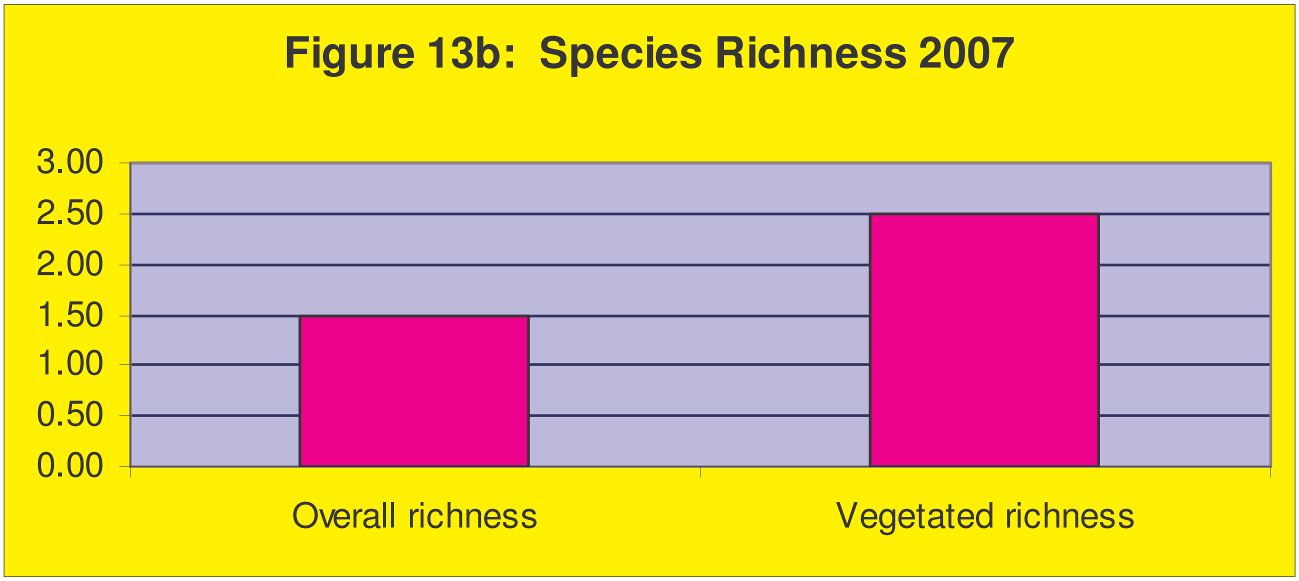
In 2009, the 0 to 1.5 feet depth zone (Zone 1) produced the highest total occurrence of plant growth. Frequency of occurrence then decreased each time as water got deeper. With zone density of growth, there was a consistent drop from the shallowest zone to the deepest zone.

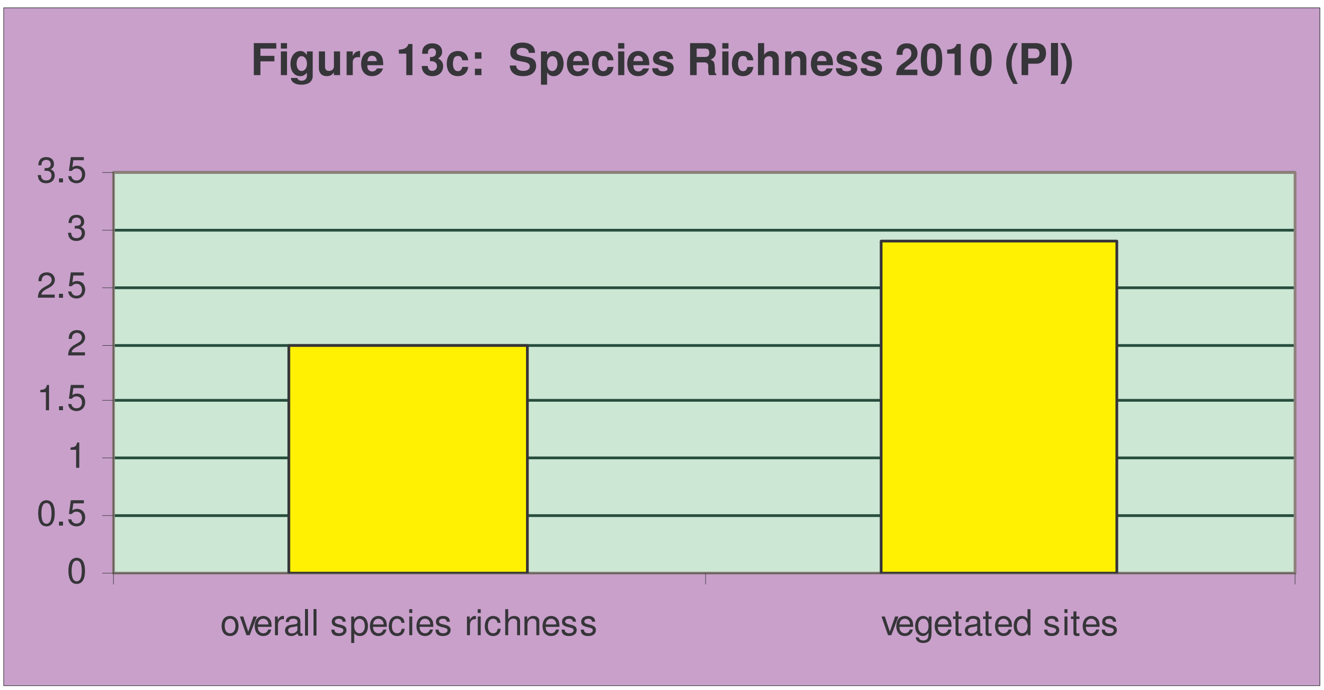


Species richness is the number of species per site. Zone 1, the shallowest zone, had the greater number of species per site (6.2) in 2009 (transect). Species richness declined as the water got deeper, dropping to only 1.2 per site by over 10 feet in depth. The species richness for the lake overall was 4.1 in 2009. It rose to 4.5 overall if just considering the vegetated sites.



Species richness under the PI method used in 2007 was substantially less. Since that is a different method, species richness information isn't divided into zones. However, the overall species richness for all sites in 2007 was 1.5. If only the vegetated sites are considered, overall species richness rose to 2.5. In 2010, the overall species richness for all sites was 2.0. Species richness at vegetated sites only was 2.9





THE COMMUNITY

The Simpson's Diversity Index in 2009 for Arrowhead Lake was .91, showing good species diversity (transect). This is the same as the 2006 SI, which was up slightly from the 2000 index of .89 (transect). The PI Simpson's Index in 2007 was .88. The

2010 SI was .91. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). The 2009 and 2010 AMCI for Arrowhead Lake is 56, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes. The AMCI in 2006 was 55, and the 2000 reading was 56. The 2007 PI AMCI was only 49. This is probably due the difference in method of plant collection, since the PI points for Arrowhead Lake included only 27 out of 525 points in water depths less than 5 feet. Based on transect survey results, in Arrowhead Lake, often the greatest variety of plants is found in waters less than 5 feet deep.

FIGURE 14: 2009 AMCI FOR ARROWHEAD LAKE (T)

Parameter		**Value**
Root depth	14	8
% litt veg	91	10
% sub	68	8
taxa #	44	10
% exotics	10	5
% sensitive	12	6
SI	0.91	9
		56

Figure 15a: Location of Submergent Aquatic Plants In Orange (T)

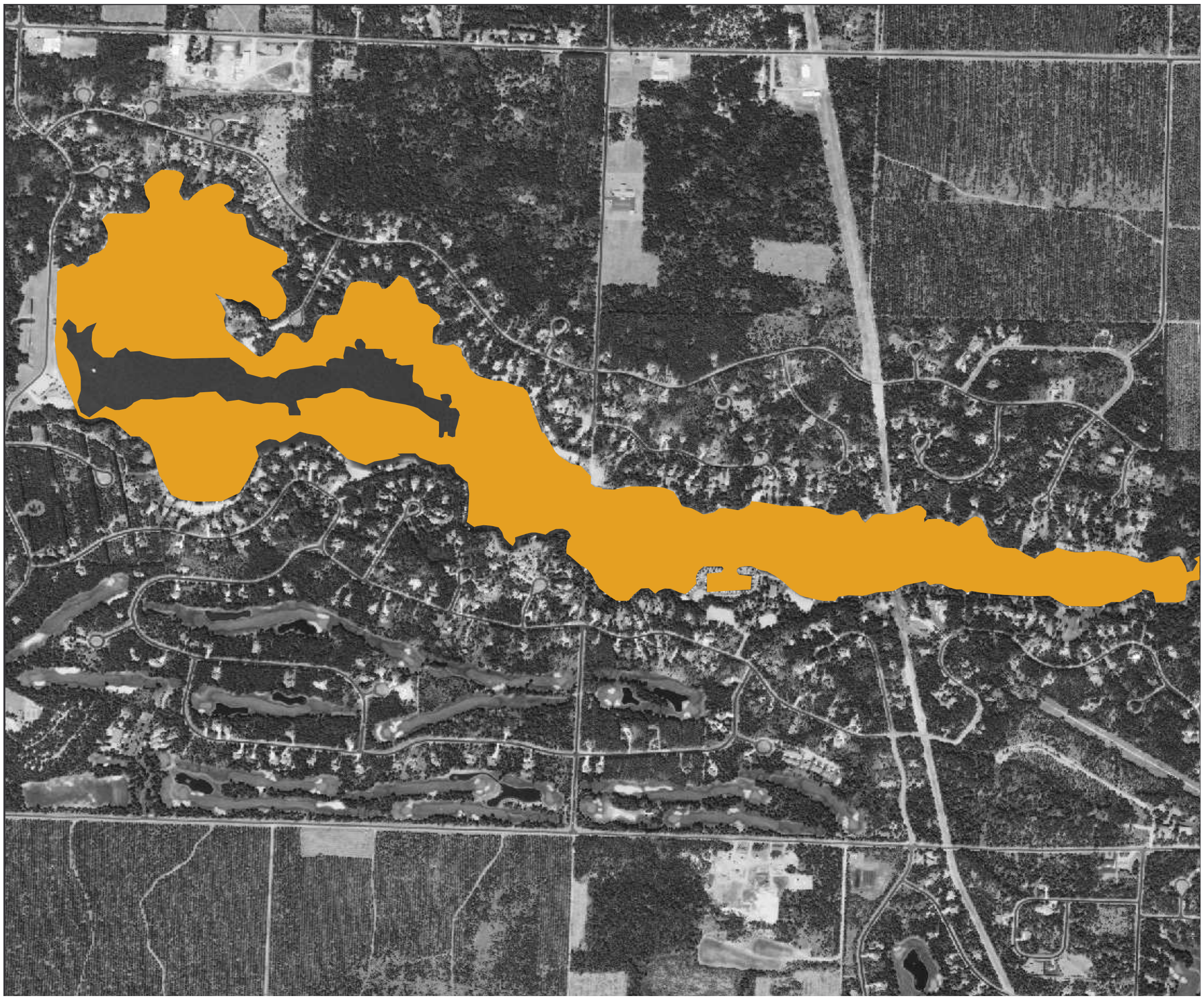
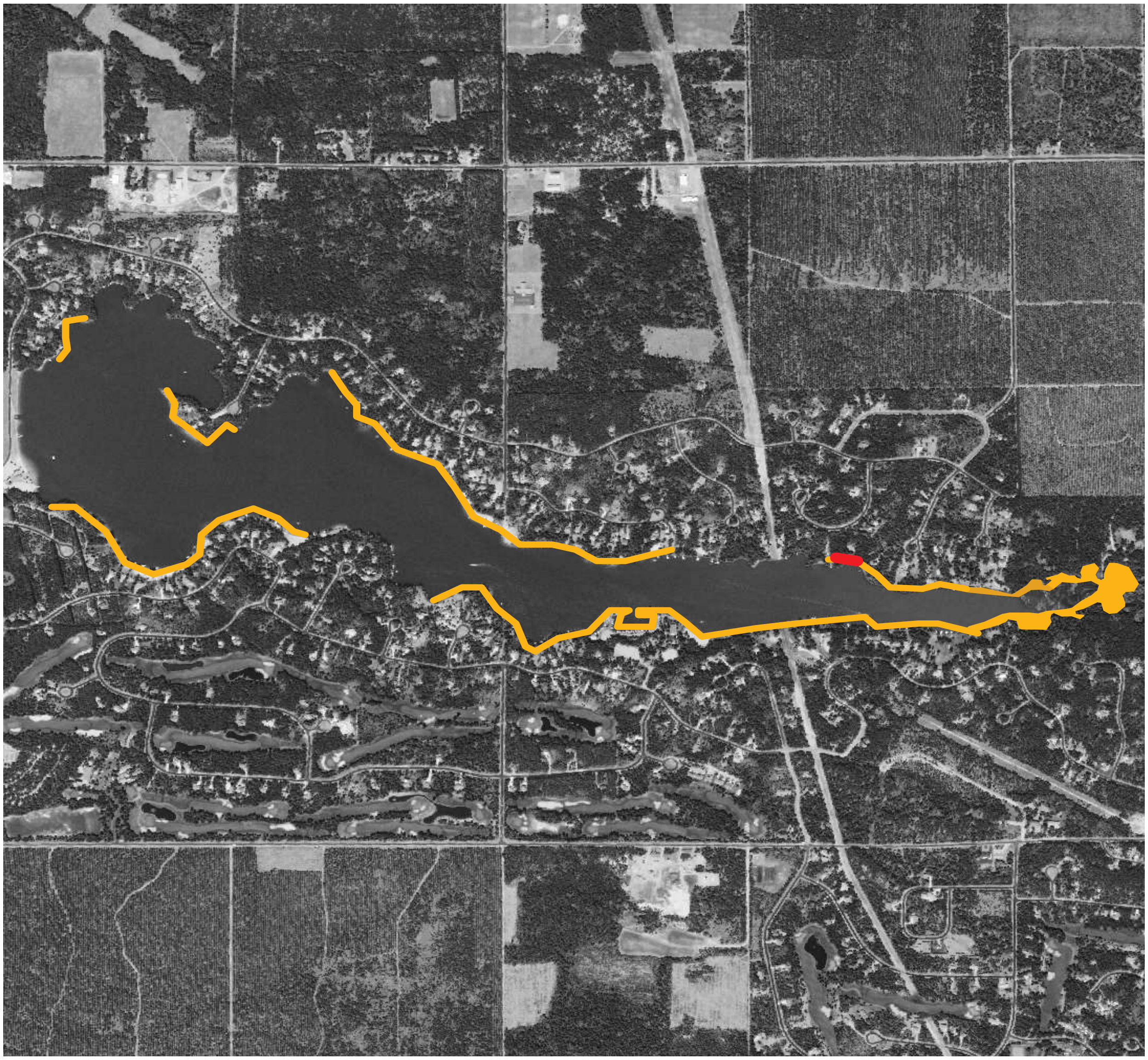


FIGURE 15b: EMERGENT AND FREE-FLOATING AQUATIC PLANTS IN ARROWHEAD LAKE 2009 (T)



Emergent Plants Found 2009

Free-Floating Plants Found 2009

The presence of several invasive, exotic species could be a significant factor in the future. Currently, none of the exotic species appear to be taking over the aquatic plant community, but both *Myriophyllum spicatum* still has a frequency of occurrence of 29.51%, up from the occurrence frequency of 27.69% in 2006. On the other hand, *Potamogeton crispus* only had occurrence frequency in 2009 of 1.64%, down substantially from the 2006 frequency of occurrence of 23.85%. It is possible that this figure somewhat under-represents *Potamogeton crispus* in Arrowhead Lake, since the survey in 2009 was done somewhat later in the summer than the one in 2006. These species should be continually monitored, since their tenacity and ability to spread to large areas fairly quickly could make them a danger to the diversity of Arrowhead Lake's current aquatic plant community.

Myriophyllum spicatum is of particular concern since it has continued to increase in frequency, despite target harvesting: in 2000, its occurrence frequency was only 1.83%; by 2006, it had grown to 27.69%; and by 2009, it had increased again to 29.51% overall. In 2000, it occurred only in depths of less than 1.5 feet, but by 2006, it was found in all four depth zones, with the highest frequency of occurrence in over 10 feet of depth. By 2009, the occurrence frequency in the deeper areas of the lake had decreased, but there was an increase of occurrence in all three of the shallower depth zones. This is in keeping with the average water clarity reading, which tops out in the 5 to 10 foot depth.

FIGURE 15c: CHANGES IN EWM IN ZONES

	Zone 1	Zone 2	Zone 3	Zone 4
2000	6.25%	0	0	0
2006	21.88%	34.38%	28.13%	40.91%
2009	25%	37.50%	40.63%	11.54%

FIGURE 15d: LOCATIONS OF AQUATIC INVASIVE PLANTS (T)

Eurasian Watermilfoil Found 2009

Reed Canary Grass Found 2009

Both EWM & RCG Found 2009

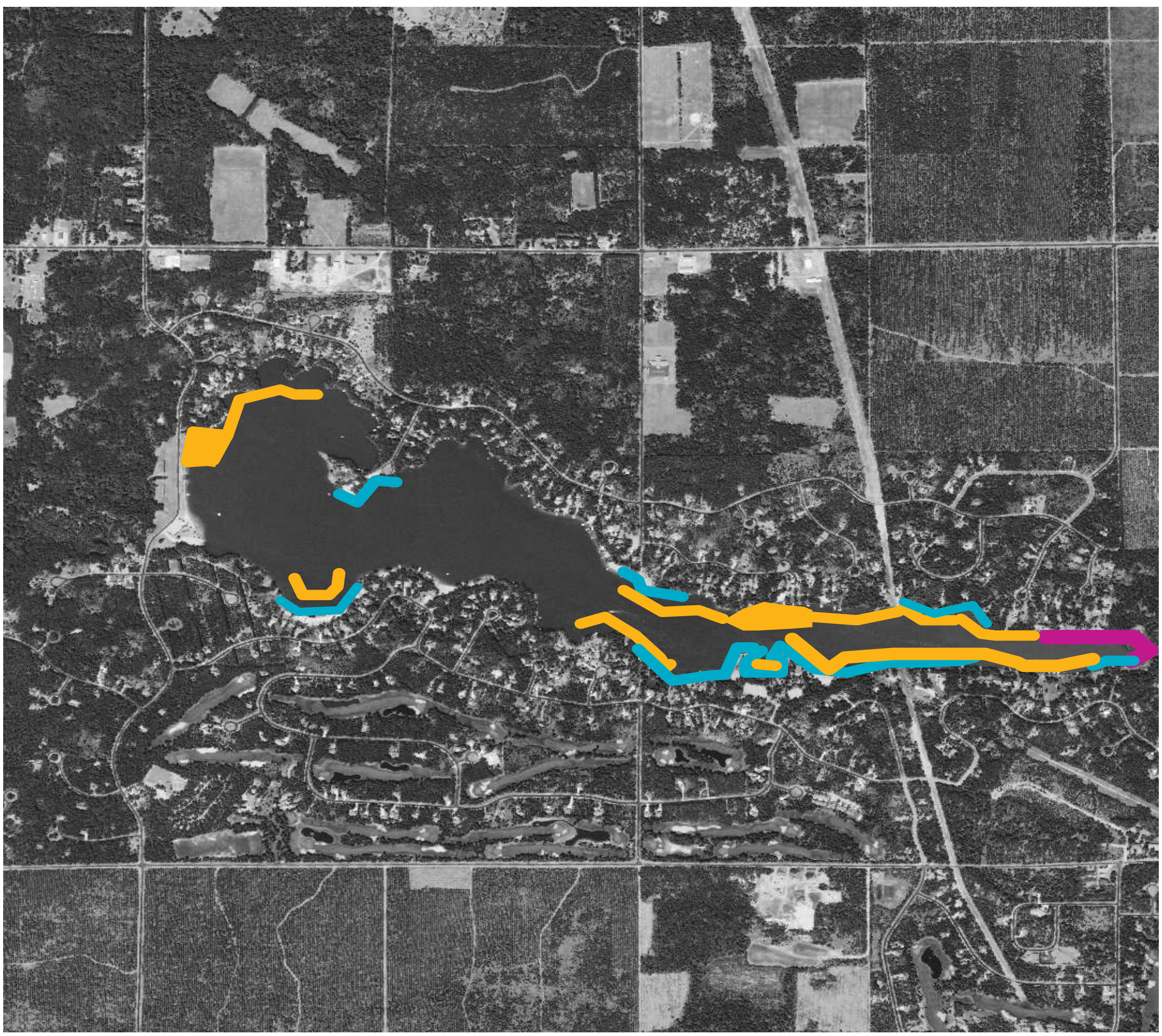


Figure 16a: AMCI for 2010 PI Survey

Parameter	Value	Score
max depth	18	10
litt veg %	68.10%	10
sub %	92.00%	7
taxa	45	10
% exot	14%	4
% sens	12%	6
SI	0.91	9
Total		56

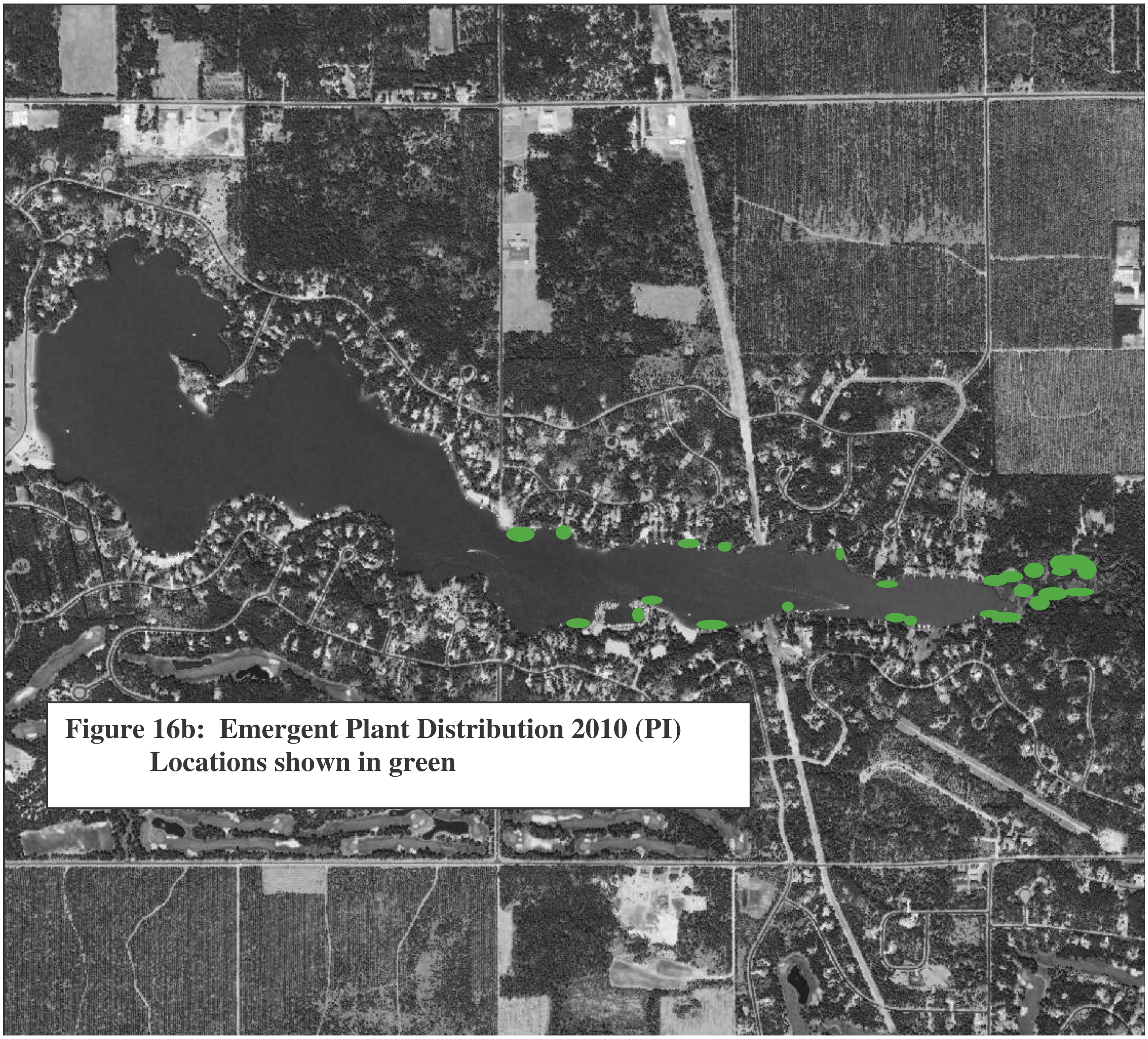


Figure 16b: Emergent Plant Distribution 2010 (PI)
Locations shown in green

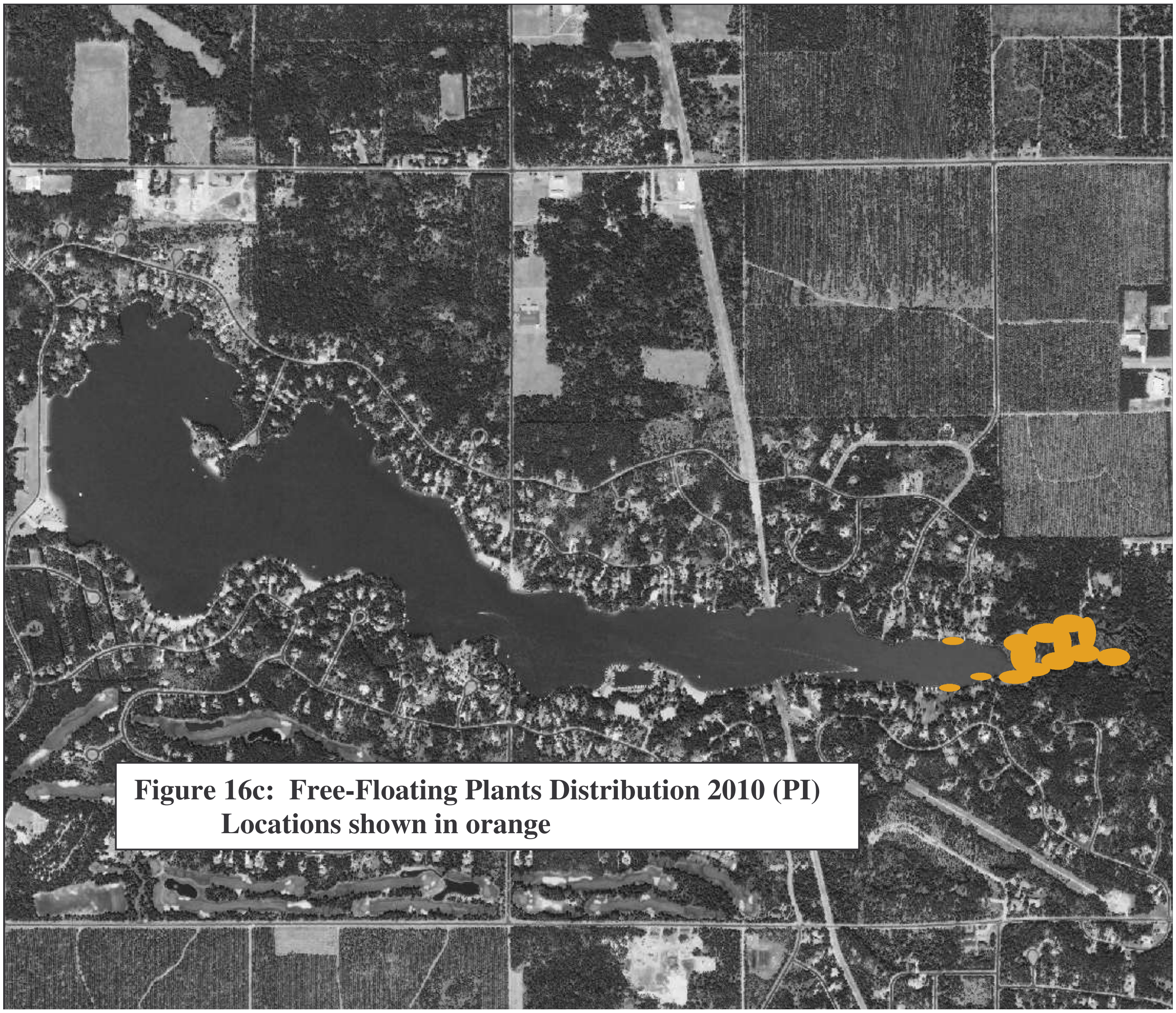


Figure 16c: Free-Floating Plants Distribution 2010 (PI)
Locations shown in orange

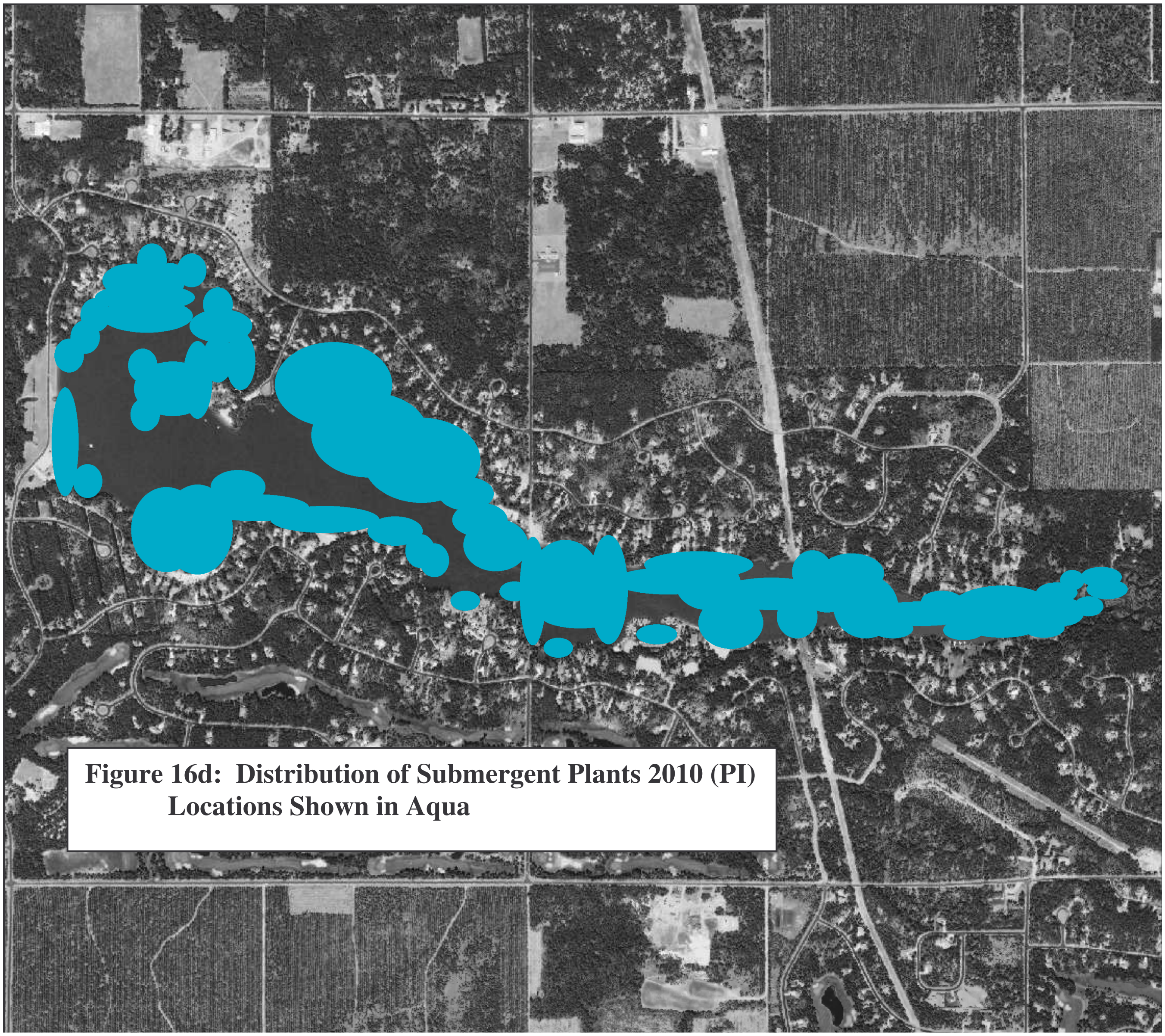


Figure 16d: Distribution of Submergent Plants 2010 (PI) Locations Shown in Aqua

Four invasive aquatic plants were found in the 2010 PI survey, just as they were in the prior surveys. The most prevalent aquatic invasive found in 2010 was Eurasian watermilfoil (*Myriophyllum spicatum*). It had an overall frequency of occurrence of 19.2% in the lake, although it did not grow at the increased density of growth shown in prior surveys. The other three invasives found—*Phalaris arundinacea, Potamogeton crispus* and *Typha angustifolia*—had 5% or less frequency of growth.

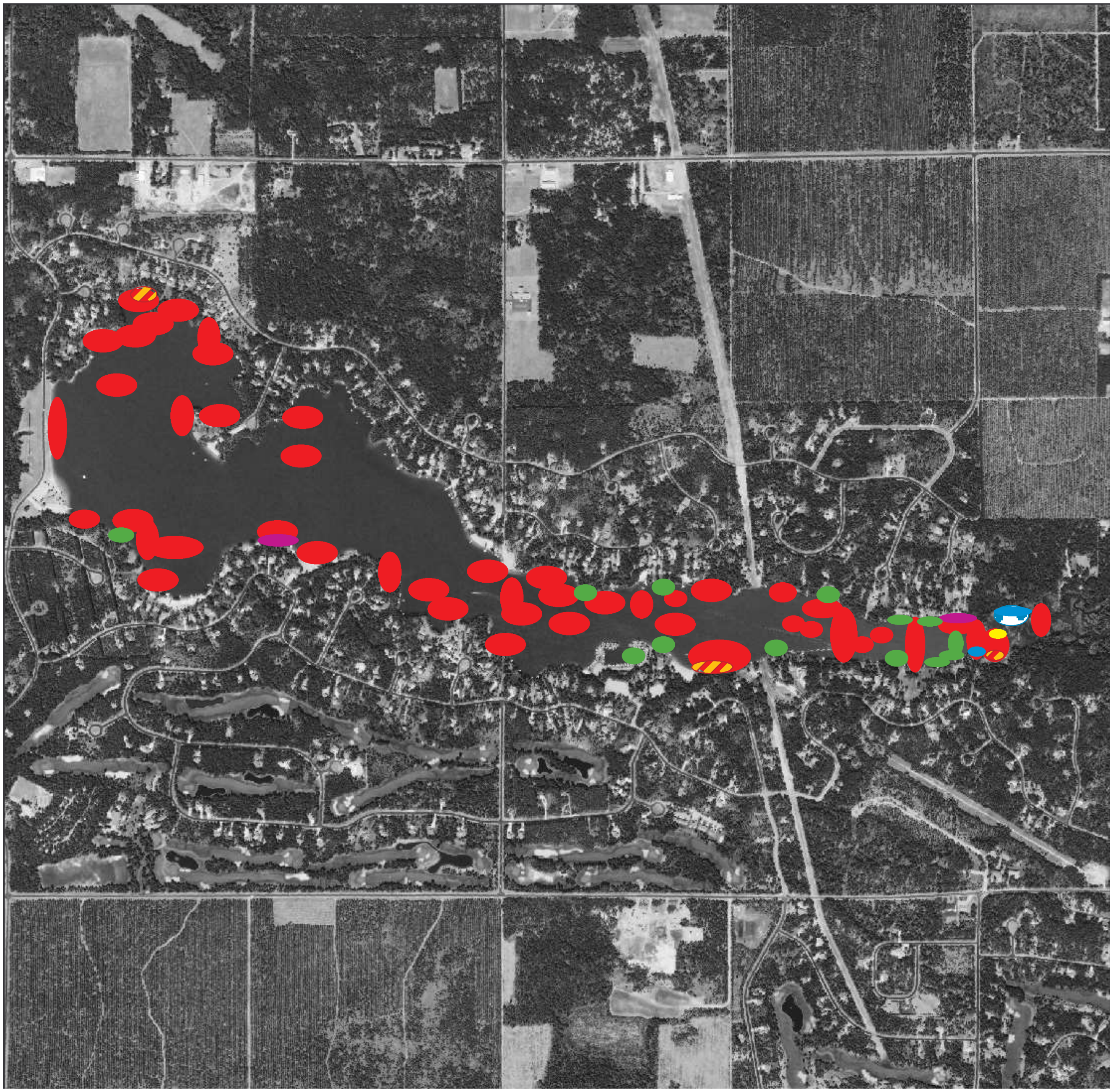


Figure 17: Distribution of Aquatic Invasives 2010 (PI)

Eurasian Watermilfoil only

EWM & Reed Canary Grass

EWM, RCG & Curly Leaf Pondweed

EWM & CLP

RCG only

EWM, CLP & Narrow-Leaved Cattail

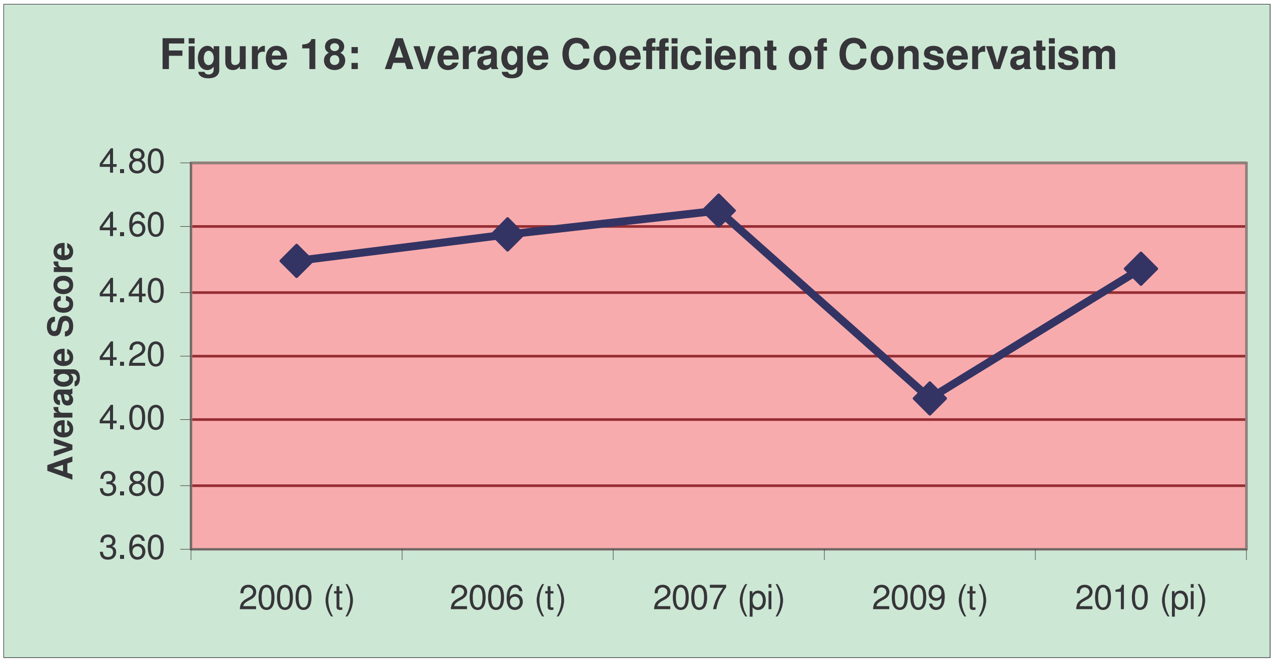
EWM & NLC

An Average Coefficient of Conservatism and a Floristic Quality Index calculation were performed on the field results in 2009 and 2010. Technically, the Average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Quality Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

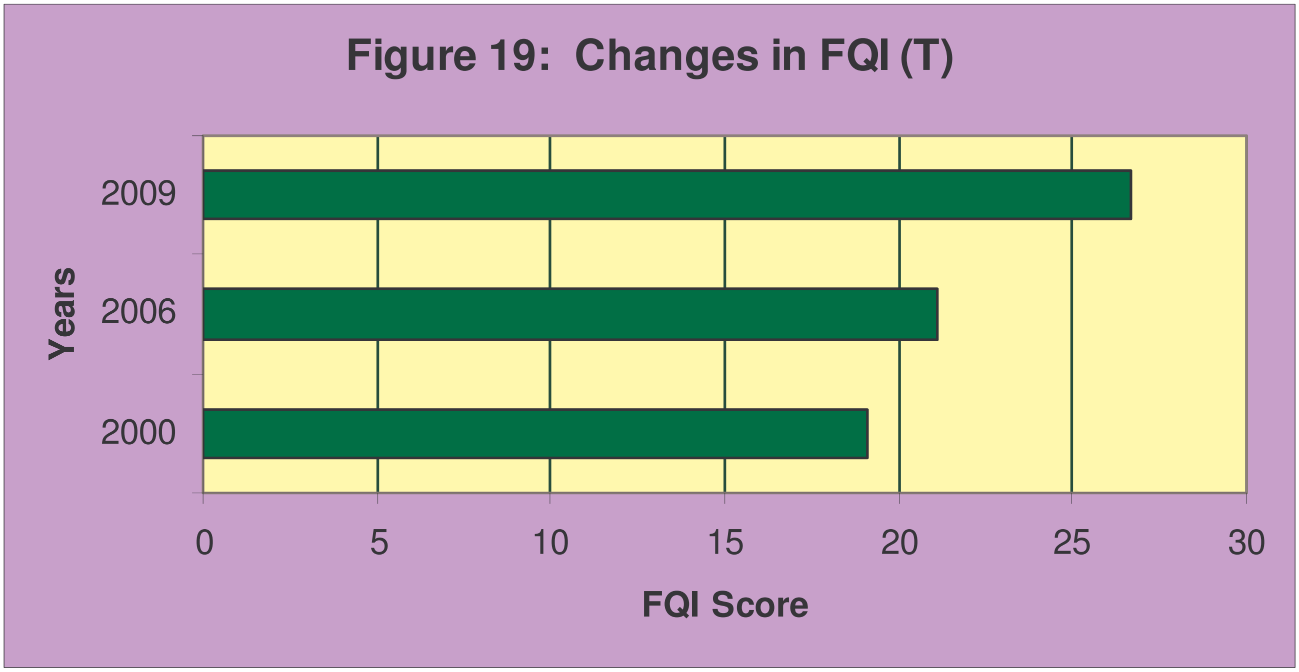
Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The Average Coefficient of Conservatism found in the Transect Survey in Arrowhead Lake in 2009 was 4.07, somewhat lower than the average COCs in 2006 and 2000. This puts Arrowhead Lake in the lowest quartile for Wisconsin Lakes (6.0) and for lakes in the North Central Hardwood Region (5.6). The aquatic plant community in Arrowhead Lake is in the category of those very tolerant of disturbance, probably due to selection by a series of past disturbances.

The Average Coefficient of Conservatism in the 2010 PI Survey was 4.47, higher than the Transect Survey results, but still putting Arrowhead Lake in the lowest quartile for both all Wisconsin Lakes and the North Central Hardwood Region. This is somewhat lower than the PI 2007 result of 4.65, but still in the same quartiles.



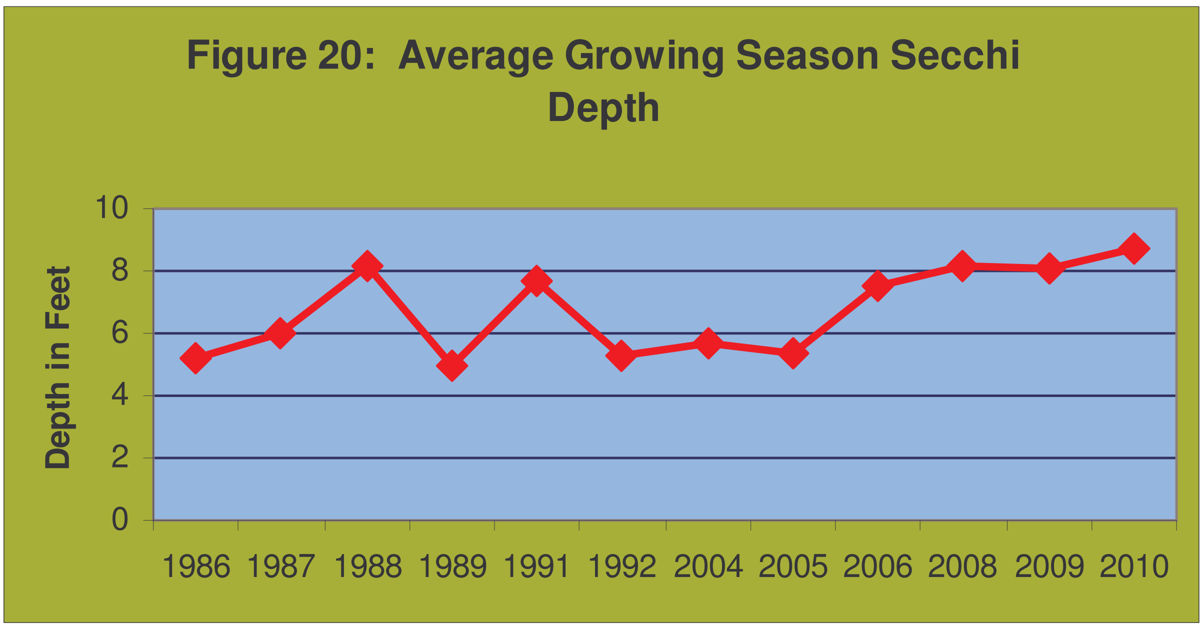
The Floristic Quality Index is a tool that can be used to identify areas of high conservation value, monitor sites over time, assess the anthropogenic (human-caused) impacts affecting an area and measure the ecological condition of an area (M. Bourdaghs, 2006). The 2009 Floristic Quality Index of the aquatic plant community in Arrowhead Lake of 26.7 is slightly above average for Wisconsin Lakes (22.2) and the North Central Hardwood Region (20.9). In prior transect surveys, such as the one in 2000, it was 19.09, slightly below average, so the FQI has increased slightly since 2000. The 2010 PI FQI was 29.96, higher than the transect survey results and considerably higher than the 2007 PI FQI of 19.19. These figures suggest that the plant community in Arrowhead Lake is making some progress to be a little closer to an undisturbed condition than the average lake in Wisconsin overall and in the North Central Hardwood Region. Using either scale, the aquatic plant community in Arrowhead Lake has been impacted by at least an average amount of disturbance, including human-caused disturbances.



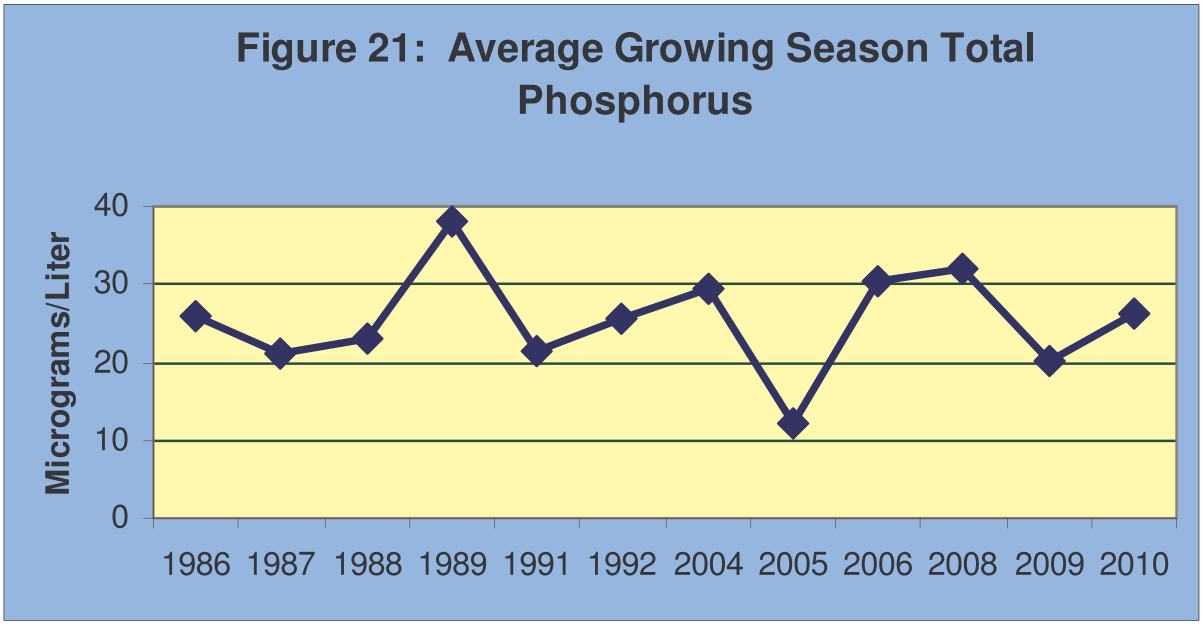
"Disturbance" is a term that covers many disruptions to a natural community. It includes physical disturbances to plant beds such as boat traffic, plant harvesting, chemical treatments, dock and other structure placements, shoreline development and fluctuating water levels. Indirect disturbances like sedimentation, erosion, increased algal growth, and other water quality impacts will also negatively affect an aquatic plant community. Biological disturbances such as the introduction of non-native and/or invasive species (such as the Eurasian Watermilfoil, Reed Canarygrass and Curly-Leaf Pondweed found here), destruction of plant beds, or changes in aquatic wildlife can also negatively impact an aquatic plant community. Shore development and sediment deposition can also reduce the quality of the aquatic plant community.

IV. COMPARISON TO PRIOR PLANT SURVEYS

Average growing season Secchi disk reading has varied over the years, with the highest being 8.2 feet (in 2008 and 1988) and the lowest average being 5 feet (1989). During the heavier drought years in the 2000s, the average growing season Secchi disk reading was only slightly above 5 feet, but with the cooler summers of the last few years, the average has risen (Figure 20).



The Arrowhead Lake overall average total phosphorus from 1986 to 2010 for the growing season was 25.6 micrograms/liter (Figure 21). The lowest average was in 2009, with a growing season average of 20.2 micrograms/liter total phosphorus. The highest was found in 2006, when the growing season average was 30.5 micrograms/liter.



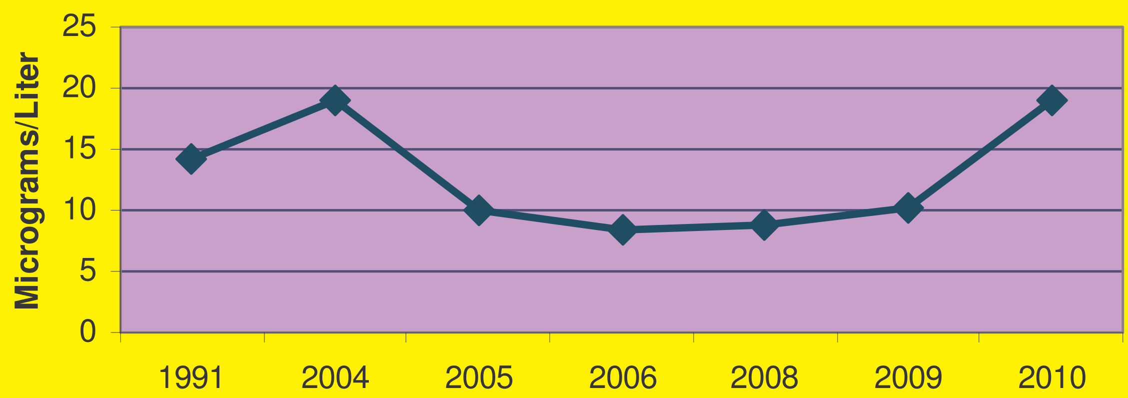
According to Understanding Lake Data (Shaw, Mechenich & Klessig2002), the average phosphorus level for impoundments in Wisconsin is about 65 micrograms/liter. The average for natural lakes is about 25 micrograms/liter. Arrowhead Lake, despite being an impoundment, has an average growing season total phosphorus at almost the average of natural lakes in the state.

Figures for chlorophyll-a levels are scarcer than those for total phosphorus and Secchi disk readings. Until the Adams County Land & Water Conservation Department started doing regular water quality monitoring in 2004, assisted by a grant from the WDNR, there was only one year (1991) for which there was chlorophyll-a level reading for Arrowhead Lake. The overall average growing season chlorophyll-a levels for Lake Arrowhead from 1991 through 2010 was 12.9 micrograms/liter.

Arrowhead Lake was found to have zebra mussels (*Dreissena polymorphya*) in 2004. The Tri-Lakes Management District, the Adams County Land & Water Conservation Department and the WDNR have been monitoring the presence every year since then using a number of methods. In August 2010, Arrowhead Lake had a significant blue-green algae bloom of *Myrocystis*. This blue-green algae bacterium has been found previously in Arrowhead Lake as well. Aquatic plants collected in both 2009 and 2010 were covered with zebra mussels of various sizes. Some of the plants were so covered that it was difficult to determine their identification. This suggests that zebra mussels have spread throughout the lake, attaching not only to docks, rocks and other hard structures, but also to grains of sand and aquatic plants (and to each other).

According to the WDNR species fact sheet on zebra mussels, the presence of zebra mussels may promote the growth of blue-green algae, since they reject blue-green algae as food, giving blue-green algae a competitive edge of algae that the zebra mussels do eat.. The National Oceanic and Atmospheric Administration (NOAA) issued a release in March 1996 indicating that not only blue-green algae tended to increase in the presence of zebra mussels because it was rejected as food, but that there may also be an increase in other algae, since zebra mussels release nutrients that encourage algal growth (Quigley, M., 1996). This may be part of the reason that algae is increasing steadily in Arrowhead Lake since 2006, about the time that zebra mussels began really spreading in Arrowhead Lake.

FIgure 22: Average Growing Season Chlorophyll-a Levels



According to the Water Group of North Carolina State University, levels of chlorophyll-a over 20 micrograms/liter are like to result in some water discoloration and some development of algal scums. This characterization is in keeping with what has been found at Arrowhead Lake: any algal scums tend to be localized, rather than wide-spread across the lake.

Comparisons were done between the plant communities of 2000 and 2006 in Arrowhead Lake to that found in 2009 (transect surveys). The biggest change since 2006 occurred in the greatly increased presence of emergent plants. In 2006, Adams County was still in a several-year drought. This had resulted in lower lake levels in all of the Tri-Lakes due to the low rainfall, very hot weather, and high evapotranspiration. However, in 2009, there had been two full winters of heavy snow fall, increasing spring moisture, and two fairly cool summers, leading to higher lake levels in 2009 than there were in 2006. In 2010, early summer was characterized by very heavy rains, so the lake level remained up.

The aquatic plant communities of 2006 and 2009 were also compared in regards to the specific plants present, as well as their actual frequency of occurrence and relative frequency of occurrence. The coefficient of similarity is an index, first developed by Jaccard in 1901, which compares the similarity and diversity of sample sets. In this instance, the figure considers the frequency of occurrence and relative frequency of all species found, then determines how similar the overall aquatic plant communities are. Similarity percentages of 75% or more are considered statistically similar (Dennison et al, 1993).

FIGURE 23: AQUATIC COMMUNITY CHANGES 2006 TO 2009 (T)

	Changes in the Macrophyte Community			
Arrowhead--2009 (T)	2006	2009	Change	%Change
			2000-2009	2000-2009
Number of Species	22	43	21.00	95.5%
Maximum Rooting Depth	16.0	14.0	-2.00	-12.5%
% of Littoral Zone Vegetated	91	91	0.20	0.2%
%Sites/Emergents	2.9	23.77	20.87	719.7%
%Sites/Free-floating	4.9	6.56	1.66	33.9%
%Sites/Submergents	92.2	74.59	-17.61	-19.1%
%Sites/Floating-leaf	0	0		0.0%
Simpson's Diversity Index	0.89	0.91	0.02	0.0%
Species Richness	3.80	4.1	0.30	7.3%
Floristic Quality	21.11	26.69	5.58	20.9%
Average Coefficient of Conservatism	4.5	4.07	-0.43	-10.6%
AMCI Index	55	56	1.00	1.8%

According to the information gained from the 2006 and 2009 transect surveys and using the coefficient of similarity index, the aquatic plant communities in those two years were 92.0% similar based on actual frequency of occurrence and 84.2% based on relative frequency. Thus, despite the increase in emergent plants, the aquatic plant communities in Arrowhead Lake in 2006 and 2009 are statistically similar.

The 2009 aquatic plant community was also compared, using the same method, to the aquatic plant community of 2000. According to those calculations, the 2009 and 2006 aquatic plant communities were 86.3% similar in frequency of occurrence and 94.9% similar in relative frequency. The 2006 and 2000 aquatic plant communities were also compared in similarity. They were 92.4% similar in frequency of occurrence and 76.9% similar in relative frequency.

These figures suggest that although some of the aquatic plant species found have changed, the aquatic plant community found in 2009 is substantially similar to that in 2000. To the extent that the aquatic plant community and water quality results mirror the health of Arrowhead Lake, it appears that Arrowhead Lake has remained relatively stable for at least the past 10 years.

FIGURE 24: AQUATIC PLANT COMMUNITY CHANGES 2000 TO 2009

Arrowhead--2009 (T)	2000	2009	Change	%Change
			2000-2009	2000-2009
Number of Species	18	43	25.00	138.9%
Maximum Rooting Depth	11.0	14.0	3.00	27.3%
% of Littoral Zone Vegetated	81	91	10.30	12.8%
%Sites/Emergents	2.35%	23.77%	0.21	911.5%
%Sites/Free-floating	2.60%	6.56%	0.04	152.3%
%Sites/Submergents	95.05%	74.59%	-0.20	-21.5%
%Sites/Floating-leaf	0.00%	0.00%	0.00	0.0%
Simpson's Diversity Index	0.89	0.91	0.02	2.2%
Species Richness	2.90	4.1	1.20	41.4%
Floristic Quality	19.09	26.69	7.60	39.8%
Average Coefficient of Conservatism	4.5	4.07	-0.43	-9.6%
AMCI Index	56	56	0	0

The structure of the aquatic plant communities has changed. Whereas in 2000 and 2006, over 90% of the aquatic plant community was submergent plants, by 2009, emergent plants had substantially increased in occurrence. Some of this increase may be attributed to the surveying staff being more familiar with a higher number of species. There also may be more emergents present because the emergent seed banks were nourished by water in 2008 and 2009, whereas in 2006 and 2007, there was a drought and areas where there are now emergents had been dried out for some time.

Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife. They also help dampen waves, thus offering some protection to erosive shores. Since much of Arrowhead Lake's shore is sandy, this protection may be very important. Also, diversity of structure in the aquatic plant community increases the diversity of fish and wildlife that can be supported by the community.

Figure 24 provides an example of some of the benefits provided to various birds, fish and mammals by some of the plants found in Arrowhead Lake in 2009.

FIGURE 25: BENEFITS OF SOME AQUATIC PLANTS

	Fish	Water Fowl	Shore Birds	Upland Birds	Muskrat	Beaver	Deer
Ceratophyllum demersum	F,I,C,S	F,I,C			F		
Chara	F,S	F,I,C					
Lemna minor	F,I,C,S	F	F		F	F	
Myriophyllum heterophyllum	F,I,C,S	F,I	F		F		
Myriophyllum sibiricum	F,I,C,S	F,I	F		F		
Najas flexilis	F.C	F	F				
Stuckenia pectinata	F,I,C,S	F,I	F		F	F	F
Potamogeton zosteriformis	F,I,C,S	F,I	F		F	F	F
Scirpus validus	F,C,I	F,C	F,C,N	F	F	F	F
Typha latifolia	I,C,S	F	F,C,N		F,C,N	F	

F = Food; I = Shelters Invertebrates; C = Cover; S = Spawning; N = Nesting

There were eight species found in 2000 and 2006 in Arrowhead Lake that weren't found in 2009. Four were emergent species; three were submergent species; and one was a free-floating species. The average Coefficient of Conservatism for these eight species was 5.6. In 2009, there were 22 species found that weren't found in either

2000 or 2006—21 of them were emergent plants and one was a submergent plant. Their average Coefficient of Conservatism was 4.1.

The 2006 survey results showed an increase in the occurrence frequency of exotic invasive species from 2000, from 10% to 16%. However, in 2009, the relative frequency of invasive aquatic plants was back down to 10%.

FIGURE 26: AMCI CALCULATIONS FOR 2000, 2006 & 2009

Parameter	2000	Value	2006	Value	2009	Value
rooting depth (feet)	15	9	16	9	14	8
% littoral zone vegetated	80.7	10	90.8	10	91.0	10
% submersed plants	73.0	9	62.0	6	69.0	8
% sensitive plants	12.0	6	17.0	7	12.0	6
# taxa found	22	9	26	10	43	10
% exotic species	10.0	5	16.0	4	10.0	5
Simpson's Index	0.89	8	0.91	9	0.91	9
		56		55		56

Comparisons were also made between the results of the 2007 PI survey and that completed in 2010. Overall results are shown in Figure 27.

Figure 27: Comparisons between 2007 and 2010 PI Surveys

Arrowhead	2007	2010	Change	%Change
Number of Species	17	45	28.00	164.7%
Maximum Rooting Depth	15.0	18.0	3.00	20.0%
% of Littoral Zone Unvegetated	39.90%	31.91%	-10.10	-52.33%
%Sites/Emergents	<1%	9.50%	9.50	100.0%
%Sites/Free-floating	1.10%	8.40%	0.07	663.6%
%Sites/Submergents	60.20%	64.20%	0.04	6.6%
%Sites/Floating-leaf	0.00%	0.00%	0.00	
Simpson's Diversity Index	0.88	0.91	0.03	3.4%
Species Richness (overall)	1.54	2.00	0.46	29.9%
Floristic Quality	19.16	29.96	10.80	56.4%
Average Coefficient of Conservatism	4.65	4.47	-0.18	-3.9%
AMCI Index	56	56	0.00	0.0%

Although the number of species found was substantially different, the PI survey results were 70% similar, based on frequency of occurrence. The additional species found in 2010 tended to have very small frequencies of occurrence. The coefficient of similarity based on relative frequency was nearly 79%. Thus, the difference based on actual frequency of occurrence overall was under the 75% figure for similarity, but the one with relative frequency figures was over. Commonly-found species varied in their overall frequency of occurrence between 2007 and 2010, but the lack of "similarity" based on actual frequency of occurrence is probably due to the increased number of emergents found in low numbers in 2010.

The only species found during the 2007 PI survey that wasn't found during the 2010 PI survey was *Potamogeton friesii* (Fries' pondweed), but there were several emergent species found in 2010 that weren't found in 2007, likely due to the addition of sites near shore: *Asclepias incarnate; Boehmeria cylindrical; Carex spp; Chelone glabra; Cornus amomum; Cornus racemosa; Cyperus bipartitus; Eleocharis palustris; Epilobium leptophyllum; Equisetum hyemale; Eupatorium perfoliatum; Ilex verticillata; Impatients capensis; Lycopus americanus; Lycopus uniflorus; Onoclea sensibilis; Phalaris arundinacea; Prunella vulgaris; Rumex crispus; Sagittaria latifolia; Salix spp; Scirpus cyperinus; Solanum dulcamara; Typha angustifolia;* and *Verbena hastata.* The only non-emergent plant found in 2010 that wasn't found in 2007 was *Potamogeton nodusus.*

Ceratophyllum demersum (coontail) went up 3.8%. Most of other commonly-occurring species went down in overall frequency of occurrence between 2007 and 2010: *Chara* spp (muskgrass) went down 21.9%; *Elodea canadensis* (common waterweed) went down 6.2%; *Myriophyllum sibiricum* (northern watermifoil) went down 6.1%; *Potamogeton zosteriformis* (flat-stemmed pondweed) went down 21.9%. The invasive *Myriophyllum spicatum* (Eurasian watermilfoil) went down 8.5%.

The most striking changes were among two submergent species: *Stuckenia pectinata* (sago pondweed), a plant which can increase from disturbances such as drawdowns, went down 55.6% in frequency of occurrence; *Zosterella dubia* (water stargrass), a plant which tends to decrease from disturbances, went up 30.1%. In the past, the two Camelot Lakes and Sherwood Lake, which feed into Arrowhead Lake, routinely drew down their water level every winter. However, this stopped in about 2007. Perhaps the change in disturbance level (less) resulted in Sago Pondweed frequency being reduced and Water Stargrass frequency increasing.

V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Arrowhead Lake is a mesotrophic impoundment lake with good water clarity and fair to good water quality. This trophic state should support substantial plant growth and occasional algal blooms. The aquatic plant survey results suggest that there is a stable aquatic macrophyte community.

Sufficient nutrients (trophic state), hard water, good water clarity, shallow lake, and nutrient-rich inputs from increased shore development at Arrowhead Lake favor plant growth. Despite the sometime limiting effect of sand sediments on aquatic plant growth, 91% of the lake is vegetated, suggesting that even the sand sediments in Arrowhead Lake hold sufficient nutrients to maintain aquatic plant growth or that there are plants present the prefer sand substrate.

Historically, many aquatic plant treatments in Arrowhead Lake were chemical. There has been mechanical harvesting to try to reduce plant growth in the last 10 years. A continued regular schedule and pattern of machine harvesting will help in removing vegetation from the lake and may somewhat help with nutrient reduction. The harvesting should also be designed to set back the growth of Eurasian Watermilfoil, not spread it further. It might also help to skim off the high density of filamentous algae and floating-leaf plants.

The lake does have a mixture of emergent, free-floating, and submerged plants. Of the 44 species found in Arrowhead Lake in 2009, 40 were native and 4 were exotic invasives. In the native plant category, 28 were emergent, 2 were free-floating plants, and 11 were submergent species. Four exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass), *Potamogeton crispus* (Curly-Leaf Pondweed) and *Typha angustifolia* (Narrow-Leaved Cattail) were found.

Ceratophyllum demersum and *Potamogeton zosterformis* were the most frequently-occurring plants in Arrowhead Lake in 2009, with occurrence frequencies of 42.62% and 47.52 % frequency. No species had an occurrence frequency over 48%. *Potamogeton zosteriormiss* was also the densest plant in Arrowhead Lake. The second densest plant was *Ceratophyllum demersum*. Based on dominance value, *Potamogeton zosteriformis* was the dominant aquatic plant species in Arrowhead Lake, but *Ceratophyllum demersum* was very close behind. Sub-dominant were *Chara* spp, *Myriophyllum sibiricum, Myriophyllum spicatum Najas flexilis, Stuckenia pectinata* and *Zosterella dubia*.

Aquatic plants occurred at 91% of the sample sites in Arrowhead Lake to a maximum rooting depth of 14 feet in 2009. The areas of native vegetation and wetland shores on the lake that should be preserved as they maintain habitat and serve as a buffer for that area. Studies have suggested that runoff from such land is substantially less than that of developed areas. There are also some areas of deep erosion on steep banks that need to be addressed to prevent tree fall (and related root ball removal from bank) and bank preservation.

The presence of several invasive, exotic species could be a significant factor in the future. Currently, none of the exotic species appear to be taking over the aquatic plant community, but *Myriophyllum spicatum* still has a frequency of occurrence of 29.51%, up from the occurrence frequency of 27.69% in 2006. *Myriophyllum spicatum* is of particular concern it has continued to increase in frequency, despite targeted harvesting. By 2009, the occurrence frequency in the deeper areas of the lake had decreased, but there was an increase of occurrence in all three of the shallower depth zones. In 2010, this plant had decreased overall in frequency of occurrence, but was still in almost all depths of sampling, from 0.8 feet of depth to over 18 feet of depth.

On the other hand, *Potamogeton crispus* only had occurrence frequency in 2009 of 1.64%, down substantially from the 2006 frequency of occurrence of 23.85%. It is likely that this figure somewhat under-represents *Potamogeton crispus* in Arrowhead Lake, since the survey in 2009 was done somewhat later in the summer than the one in 2006. Although the 2010 survey was done in mid to late July, and found a curly-leaf pondweed frequency of occurrence of 1.1%, this survey likely also underrepresents that frequency, since the plant often dies off by then. This species should still be continually monitored, since their tenacity and ability to spread to large areas fairly quickly could make them a danger to the diversity of Arrowhead Lake's current aquatic plant community.

Of the 47 species found in Arrowhead Lake in 2010, 43 were native and 4 were exotic invasives. In the native plant category, 27 were emergent, 3 were free-floating plants, and 13 were submergents. The same four exotics were found in the PI survey in 2010 as in the transect survey in 2009. The most frequently-occurring plants were *Ceratophyllum demersum* and *Zosterella dubia. Ceratophyllum demersum* was the species with the densest growth, with *Myriophyllum spicatum* the next densest. However, no plants in the 2010 survey had a more than average density of growth. *Zosterella dubia* was the dominant plant in the 2010 survey, with *Ceratophyllum demersum* sub-dominant.

Two exotic invasives, *Phalaris arundinacea* (reed canary grass) and *Typha angustifolia* (narrow-leaved cattail) were not found during the 2007 PI survey, so there is no point of comparison for the 2010 PI survey. In 2010, reed canary grass had an overall frequency of only 5.3% and narrow-leaved cattail had only 0.88%.

The Simpson's Diversity Index in 2009 for Arrowhead Lake was .91, showing good species diversity. This is the same as the 2006 SI, which was up slightly from the 2000 index of .89. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). The AMCI for Arrowhead Lake is 56, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes. The AMCI in 2006 was 55 and the 2000 reading was 56.

The Average Coefficient of Conservatism is lower than it was in prior surveys. However, Species Richness and the Floristic Quality Index went up from both 2000 and 2006. The plant community overall has stayed fairly similar in the last 10 years.

It is worth noting that the report on the 2000 aquatic plant surveys mentioned the absence of emergent plants in Arrowhead Lake. The 2010, 2009 and 2006 surveys suggest that emergent plants seem to be "coming back", i.e., are re-establishing in Arrowhead Lake, although some of the increase may be due to the changes in sampling technique. Whether this increase will stabilize will depend on a number of factors, including continued shore development, recreational uses of the lake, and weather patterns. Different sampling techniques could also change the results. At this time these increases tend to be localized. Arrowhead Lake continues to be devoid of rooted floating-leaf plants that provide habitat for fish and invertebrates.

VI: CONCLUSIONS

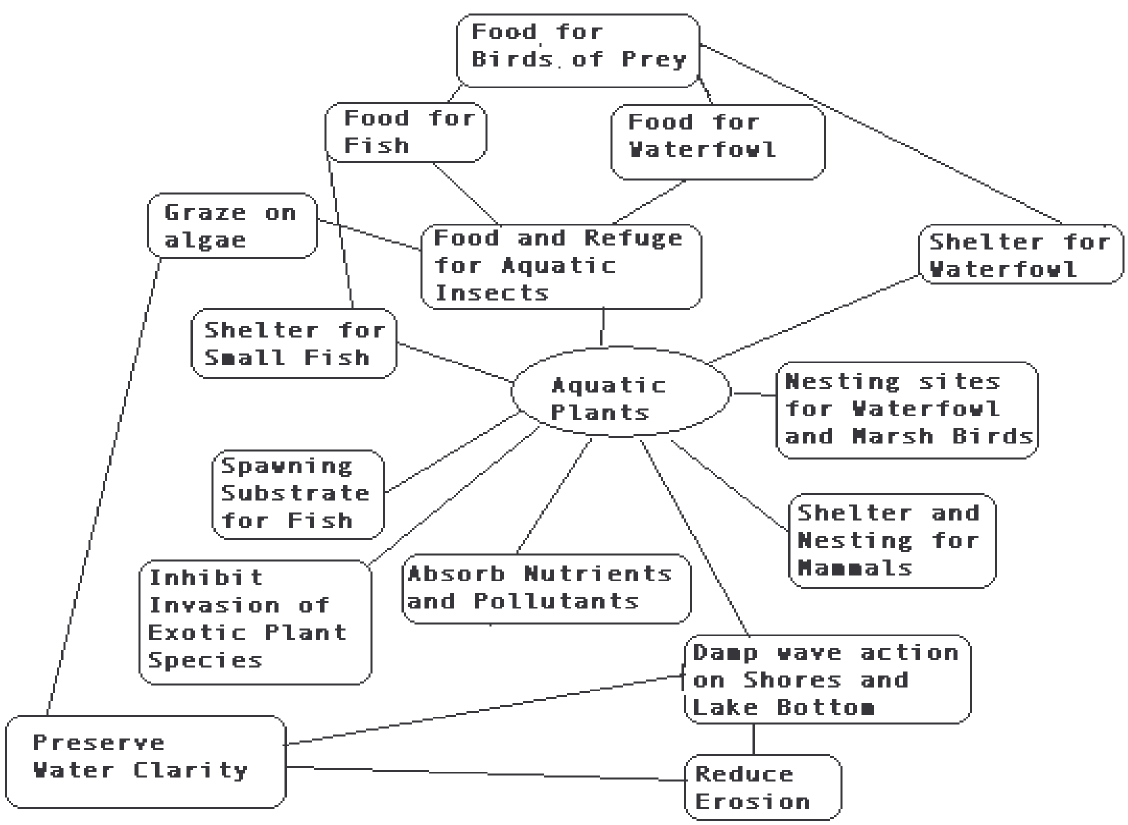
Arrowhead Lake is a mesotrophic to oligotrophic impoundment with good water quality and water clarity. The Average Coefficient of Conservatism of the aquatic plant community in Arrowhead Lake is in the lowest quartile for Wisconsin lakes and for lakes in the North Central Hardwood region, but the lake has a slightly above average Floristic Quality Index. The AMCI is in the average range for both North Central Hardwood Region and all Wisconsin lakes, indicating an aquatic plant community of average quality. Filamentous algae are abundant and have increased since 2000. Structurally, the aquatic plant community contains emergent plants, free-floating plants, and submergent plants, with the 1.5'-5' depth zone supporting the greatest amount of plant growth.

When the aquatic plant survey was performed in 2009, 91% of the littoral zone was vegetated. The potential for plant growth in most of the depths of the lake is present, even with many of the lake sediments sandy.

A healthy and diverse aquatic plant community plays a vital role within the lake ecosystem. Plants help improve water quality by trapping nutrients, debris and pollutants in the water body; by absorbing and/or breaking down some pollutants; by reducing shore erosion by decreasing wave action and stabilizing shorelines and lake bottoms; and by tying-up nutrients that would otherwise be available for algae blooms. Aquatic plants provide valuable habitat resources for fish and wildlife, often being the base level for the multi-level food chain in the lake ecosystem, and also produce oxygen needed by animals.

Further, a healthy and diverse aquatic plant community can better resist the invasion of species (native and non-native) that might otherwise "take over" and create a lower quality aquatic plant community. A well-established and diverse plant community of natives can help check the growth of more tolerant (and less desirable) plants that would otherwise crowd out some of the more sensitive species, thus reducing diversity.

FIGURE 28: LAKE ECOSYSTEM WEB



Vegetated lake bottoms support larger and more diverse invertebrate populations that in turn support larger and more diverse fish and wildlife populations (Engel, 1985). Also, a mixed stand of aquatic macrophytes (plants) supports 3 to 8 times more invertebrates and fish than do monocultural stands (Engel, 1990). A diverse plant community creates more microhabitats for the preferences of more species.

MANAGEMENT RECOMMENDATIONS

1) Because aquatic vegetation is used by fish for a number of purposes (cover, feeding, spawning, etc), continued harvesting to open fishing lanes should continue in these areas. Removal should occur by hand in the shallower areas to be sure that entire plants are removed and to minimize the amount of disturbance to the sediment.

2) Some natural shoreline restoration and erosion control in several areas is still needed, especially on some of the bare steep points. Starting in 2010, the Arrowhead Lake Association, working with the Adams County Land & Water Conservation Department, will begin to restore several severely eroded points that it owns. Some treefall at various points have already taken large portions of the banks. These shore restoration designs will be tailored to the needs of the particular shore and will probably include combinations of planting, grading, bioengineering and armoring.

3) To protect water quality, a buffer area of native plants needs to be restored on those many lake association-owned sites that now have seawalls or have traditional lawns mowed to the water’s edge. Although the Arrowhead Lake

Association owns the first hundred feet shoreward around the lake, they have been working with the landowners who use the shore area in front of their respective lots to install shore protection and provide buffers.

4) There are several points on the lake that consist of high bluffs with a great deal of sloughing soil and some falling trees. Within the last two years, the Arrowhead Lake Association has started working with Adams County Land & Water Conservation Department to restore and protect these points to prevent further erosion and soil deposit into the lake. It is recommended that this process continue until all these points have been protected and stabilized.

5) The Tri-Lakes Management District and the Arrowhead Lake Association should continue to cooperate with the WDNR to monitor and, if possible, control the zebra mussel infestation in the lake to protect the aquatic plant community.

6) Stormwater management of the many impervious surfaces around the lake is essential to maintain the current quality of the lake water and prevent further degradation.

7) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore. The new state ban on phosphorus-containing fertilizer should help, but non-Wisconsin residents need to be reminded that using phosphorus-containing fertilizers from other states is illegal.

8) The aquatic plant management plan should continue to be reviewed annually. The mechanical harvesting plan should be revised to exclude the targeted

harvesting for Eurasian Watermilfoil (EWM) that has been done in the last few years. Due to the significant increase in EWM, despite targeted harvesting, alternate methods of addressing EWM growth need to be developed.

9) The aquatic plant management plan also needs to address managing the Curly-Leaf Pondweed growth. This invasive appeared since the 2005-2006 aquatic plant surveys. If the plan is modified to include a series of actions to address this growth, perhaps its spread and establishment can be reduced.

10) The Tri-Lakes Management District may want to continue to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

11) No broad-scale chemical treatments of native aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

12) Fallen trees should be left at the shoreline or in the water to increase shore area habitat.

13) The Tri-Lakes Management District should continue involvement in water quality and invasive species monitoring through the Citizen Lake Monitoring Program, the Clean Boats, Clean Waters program and grants for AIS management.

14) Arrowhead Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs. Nutrients

appear to have increased within the lake, so residents must take steps to reduce their nutrient inputs.

15) No drawdowns of water level except for DNR-approved purposes should occur.

16) The few sites where there is undisturbed shore, mostly in designated conservancy areas, should be maintained and left undisturbed.

17) The Tri-Lakes Management District should continue to review its lake management plan at least annually and continue to engage in water quality testing that ensures that its lake management plan takes into account all inputs from both the Arrowhead Lake surface ground watershed and inputs from Camelot & Sherwood Lakes, and addresses the concerns of this larger lake community.

18) Cooperation with the Adams County Parks Department in keeping the boat ramp and swimming beach in safe condition should help reduce any negative impacts caused by the heavy use of these public areas. A boat washing station at the park ramp area may help in decreasing other invasives from invading the lake.

19) The Tri-Lakes Management District, which includes Arrowhead Lake, has become a sanitary district and now requires tri-annual inspection of all septics, no matter what their date of installation. This program needs to continue, especially since at 1999 report of the lake area septic systems by MSA Professional Services found that septic absorption fields around the Tri-Lakes develop phosphorus loads in a shorter-than-anticipated time that may end up in the lake through groundwater flow, so that regular inspections may help

reduced this buildup and discharge. Until Adams County gets its county program for regular inspection up and running for older septic system, the Tri-Lakes Management District should continue with the program it has already set up to make sure there aren't problems in the meantime.

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